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THESIS

ANNUAL SCHEDULING OF ATLANTIC FLEET NAVAL COMBATANTS

by

Clarke E. Goodman Jr.

March 1985

Thesis Advisor: R. Kevin Wood

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This study provides a mathematical programming model to assist employment scheduling. A set covering formulation of the scheduling problem minimizes deviations from an "ideal" schedule, developed in terms of navy scheduling policy, while satisfying event requirements. An efficient column generation program, using problem-specific column reduction techniques, produces a moderate sized problem which is then solved as an integer program.

The model is tested using data from the 1983 Atlantic Fleet schedule for carriers and surface combatants. The data involving 111 ships, 19 major events, 73 separate ship-type requirements, and 44 force weapon system capability requirements yields a set covering problem with 10,723 variables and 228 constraints. This problem is solved on an IBM 3033 AP in 84 seconds of CPU time.

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Annual Scheduling of Atlantic Fleet Naval Combatants

by

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Lieutenant, United States Navy
B.S., Miami University, 1977

Submitted in partial fulfillment of the
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I. INTRODUCTION

> In its broadest sense, fleet readiness is the degree to which the force is ready to carry out its mission to wage prompt and sustained combat at sea. Supporting military strategy involves not only having units properly manned, trained, equipped, and supported, but also deployed to positions from which they may be able to best support U.S. interests and rapidly engage potential enemies....A properly balanced employment schedule is essential to attain high states of readiness, because the individual requirements for maintenance, training, and morale are frequently in competition with each other. [Ref. 1]

Employment scheduling is the process whereby U. S. Navy ships, submarines, aircraft and other units are assigned to major operations, exercises, maintenance periods, inspections and other events. The effectiveness of the employment scheduling process directly influences overall fleet combat readiness. Currently, this process is largely manual requiring several full time scheduling officers and additional personnel at various levels of management. This study develops and implements an optimization model that automates a substantial part of the employment scheduling problem. The model is formulated as a generalized set covering problem and may be applied to a number of independent subsets of the employment scheduling problem. For explanatory purposes, the model is applied to the annual planning schedule for naval combatants of the Atlantic Fleet.

A. CURRENT PROCEDURES

The Atlantic Fleet Employment Schedule details the day-to-day operations of the 700 to 750 units that comprise the Atlantic Fleet. The schedule is one of the primary methods for managing these fleet assets. Requests for fleet units to participate in events, referred to as *event requests* in this study, originate from several sources, e.g., Secretary of Defense, Chief of Naval Operations, Type Commanders, Fleet Commanders, Group Commanders, Squadron Commanders, and individual unit commanders. Fleet assets are always in short supply relative to the demands resulting from all event requests. Fleet schedulers are faced with the problem of selecting which event requests will be scheduled and how to most efficiently schedule those events. The size and complexity of this scheduling problem demands the resources of numerous management personnel, e.g., operation and planning staffs, at all levels in the command structure.

Current Navy employment schedules are produced with little computer assistance. The Commander in Chief Atlantic Fleet (CINCLANTFLT) convenes a scheduling conference each quarter. This conference is the culmination of the employment scheduling process and results in publication of a detailed quarterly employment schedule with annual schedule projections. CINCLANTFLT's conference is preceded by Type Commander scheduling conferences. The Type Commander conferences are the working conferences where schedules are developed. At these conferences, rough schedules are proposed, reviewed, discussed, conflicts resolved, and bargains made until a final schedule is selected for submission to CINCLANTFLT. In the overall process, computers are only used to store and retrieve schedule data; they are not used to assist decision-making.

CINCLANTFLT is the overall schedule coordinator. Fleet assets are managed by the Type Commanders who, in turn, delegate part of their management responsibilities to group, squadron and unit commanders. CINCLANTFLT and the operational fleet commander (OPFLT) are primarily concerned with meeting major operational commitments while Type Commanders and lower levels of command are principally concerned with maintenance, inspections, and training.

B. PROBLEM SCOPE

The entire employment scheduling problem is formidable. However, because of its structure, the problem can be divided into independent subproblems of manageable size. This study develops a model for the *Combatant Primary Event Schedule* (CPSKED) problem. The derivation of this problem from the overall employment scheduling problem is discussed in this section; the resulting CPSKED problem is defined in detail in Chapter II.

CINCLANTFLT has operational commitments in the home fleet (Second Fleet) and abroad. These commitments result from event requests that have been approved for inclusion in the fleet schedule and are referred to in this study as *primary events*. Primary events include all extended operations and major exercises. These events are the most important and the most demanding events in the fleet schedule. Other events are classified as either *major maintenance events* or *secondary events* and may be viewed as events necessary to support the successful conduct of primary events.

This study focuses on scheduling ships to the CINCLANTFLT primary events. It is assumed that (1) all primary events are fixed in start time and duration, and (2) all primary events are uniformly more important than supporting events. Assumption 1 effectively separates the process of the timing of primary events from the problem of scheduling (assigning) ships to these events. This is a good approximation of current Naval practice since most commitments are made years in advance without detailed knowledge of future fleet assets, and also because of long-term fixed commitments. Assumption 2 allows assignment of ships to primary events without requiring concomitant scheduling of secondary events, although time must be set aside in a ship's primary event schedule to allow for subsequent scheduling of secondary events. Thus, with the above assumptions the problems of determining which events to schedule and when to schedule them are presumed solved. The remaining problem is to determine which fleet assets should be used to satisfy the primary event requirements while distributing the workload equitably among the ships.

Fleet assets may be divided into the following functional categories: naval combatant units, amphibious units, marine units, support units, submarine units, and aviation units. Within a functional category, unit operational capabilities are similar and units are employed in similar missions. Hence, substitutions within a functional category may be allowed but substitutions across category bounds are not allowed. Primary events may require assets from one or more of these functional categories; however, since substitutions are confined to functional categories, an individual asset requirement for a primary event is dependent on only one functional category. Consequently, the CPSKED model can be developed to generate annual planning schedules for assigning assets from one functional category, naval combatants in this study, to primary events without regard to other functional categories. Primary event scheduling problems considering other functional categories, e.g., amphibious units, aviation units, submarines, or support ships, can be formulated in a manner analogous to the methods presented in this study.

An instance of the CPSKED problem consists of 19 primary events and 111 ships based on 1983 historical data. The primary events may require assets by ship-type and/or weapon system capability. The 19 primary events translate to 73 event/ship-type requirements and 44 force weapon system capability constraints. The goal is to select the best annual planning schedule from all possible candidate schedules.

C. THE NEED FOR COMPUTER ASSISTANCE

Scheduling decisions directly affect fleet readiness and fleet operational performance.

> The optimized peacetime employment schedule which has as its objective maximizing combat readiness should always be the goal and guide. [Ref. 1]

Unfortunately, readiness is a vague measure which cannot be directly optimized. However, computers can be used effectively as management tools to assure that the employment schedule provides the best opportunity to maintain readiness at the highest level possible.

The opportunity to maintain readiness can be measured in terms of efficient utilization of fleet assets. The unnecessary over-employment of fleet assets adversely affects personnel morale and reduces the opportunities for maintenance and training. While over-employment is considered more detrimental to fleet readiness, under-employment results in deficiencies in operational experience with a consequent reduction in overall readiness. Thus, the effect of either over-employment or under-employment of fleet assets is a reduction in fleet readiness. In addition, assignment of a suboptimal mix of forces and capabilities to perform an operational mission or major exercise will result in degraded performance and, in the extreme, may result in failure to achieve the objectives of the mission or exercise.

Navy employment schedules have been successfully produced for years without the assistance of computers or computer models. Furthermore, because of the unpredictable nature of ships and navy operations, it is unlikely that computer models will ever be sufficiently sophisticated to replace fleet schedulers. Computer models can, however, become valuable tools to assist fleet schedulers. Computer models may be used to speed up the process of generating a schedule and conduct "what-if" analysis on a schedule proposal. Additionally, an optimization model can provide a method of measuring the relative merit of different schedule proposals.

Currently, there exist no concrete methods for judging the acceptability of a proposed schedule. Experienced schedulers have an intuitive feeling, based on Navy policy and guidelines, about the merit of a proposed schedule. The mathematical modeling process requires that the scheduler's intuition be replaced by concrete rules and measurable criteria, yielding an analytic framework for comparing proposed schedules. Thus, the modeling process provides additional insight into the scheduling problem and results in a standardized method for evaluating a proposed schedule. The ability to critically evaluate and compare alternative proposals is potentially the greatest management tool to be gained from automating the scheduling process through the use of an optimization model.

D. CPSKED SOLUTION STRATEGY

CPSKED is an optimization scheduling tool developed and implemented as a set covering model. "Optimization" increases the model's power as a decision support system and "set covering" provides model flexibility and precision. Large-scale set covering models, despite their advantages, are generally considered difficult or impossible to solve. This section provides the rationale, based on modeling concepts and experience gained from prior research, for selecting this approach to solve the primary event scheduling problem.

Because of their combinatorial nature, scheduling problems are difficult to solve optimally. Consequently, many suboptimal, heuristic techniques have been developed for attacking scheduling problems. However, optimization should be preferred over suboptimal techniques because optimal solutions provide a proper reference for judging the acceptability of all alternative schedules. Geoffrion and Powers [Ref. 2] have stated the need for optimization:

> The problem is not that optimization capability is needed to cope with the staggering number of alternatives...although this is important. It is not that optimization capability is needed to resolve the cost trade-offs inherent in planning, although this too is important. It is not even that managers would rather have the best answers possible from their planning support systems, although certainly this is compelling. Rather, the crux of the matter is that optimization capability is needed to permit reliable comparisons between different runs of the model.

Therefore, the goal of this study is to develop a model and solution techniques that reliably provide optimal solutions to the CPSKED problem.

Scheduling problems can frequently be viewed as selection models, e.g., route selection, crew selection, etc. In the CPSKED problem, a set of individual ship schedules must be selected such that demands for ship-types and weapon system capabilities required by different events are satisfied. Selection problems may be formulated as set covering or set partitioning problems. In terms of a scheduling problem, the objective of a set covering model is to select a minimum cost set of schedules such that all demands for service are at least minimally satisfied or "covered." When the problem constraints are stated as equalities, i.e., demands must be satisfied exactly, the problem is referred to as a "set partitioning" or "equality constrained set covering" problem. The CPSKED problem is formulated here as a set covering problem with certain generalizations.

In the CPSKED problem, variables correspond to individual ship schedules and constraints correspond to primary event requirements. Event requirements are stated in terms of force composition (ship-types) and force weapon system capabilities. The basic development of the model is discussed in Chapter III.

Set covering problems represent a class of integer programming problems which is simple in concept. Unfortunately, like most integer programming problems, set covering problems are quite difficult to solve. However, recent advances in solution techniques have made possible the solution of large problems. (See Bausch [Ref. 3] for a survey of these computational advances.) Brown, Graves, and Ronen [Ref. 4] have applied the set partitioning model to a crude oil ocean tanker scheduling problem. Their large-scale problems (74 constraints and greater than 7,000 binary variables) were typically solved in less than one minute of IBM 3033 CPU time. Their success is based on the X System [Ref. 5] which is an advanced general purpose optimization system. Since this system is available at the Naval Postgraduate School, it is employed as the solver for the CPSKED set covering problem.

The set covering approach allows many of the real-world modeling constraints to be included in problem generator versus the problem solver. This allows for flexible and precise modeling. Essentially, the problem generator generates columns of the integer programming constraint matrix, each of which corresponds to a feasible schedule. As Bausch [Ref. 3] states "The art of

B. THE CPSKED PROBLEM

The overall employment scheduling problem involves scheduling primary, secondary, and major maintenance events for all operating forces in the Atlantic Fleet. Several independent subproblems may be identified in the overall employment scheduling problem. Divisions can be made in terms of fleet assets and event types. The CPSKED problem is an example of one of the possible independent subproblems.

1. Division by Fleet Assets

As mentioned earlier in this chapter, fleet assets include a wide variety of units performing very different functions. With respect to primary event scheduling, each of these functional categories is independent since a unit in one functional category cannot perform the mission of a unit in a different category. In primary event scheduling, mission capability is the primary consideration and the primary event scheduling problem can be divided into subproblems by functional category.

2. Division by Event Types

Major maintenance events are dependent on a unit's employment cycle and are scheduled based on shipyard availability and optimum maintenance cycles. Major maintenance schedules are developed prior to scheduling other events. Units scheduled for major maintenance become non-operational (CNOR) assets; thus, the effect of scheduling major maintenance is to limit the quantity of available operational assets for subsequent primary event employment scheduling.

Primary events are the "end products" of all fleet activity during peacetime and receive the highest priority when scheduling operational fleet assets. Primary event requirements cannot be satisfied by CNOR assets.

Secondary events are scheduled by individual units after primary event requirements have been satisfied. Secondary events are unit maintenance, training, and exercise events necessary to maintain unit readiness to support fleet operations.

Division of the overall scheduling problem by event types leads to a hierarchical ordering of the overall scheduling problems. First, solve the major maintenance scheduling problem and determine operational unit availability. Second, solve the primary event scheduling problem. Third, solve the secondary event scheduling problem using the remaining unscheduled time.

3. Primary Event Scheduling Problems

Primary event scheduling problems exist for each of the functional categories. For model development, the combatant functional category is used (thus, CPSKED for Combatant Primary Schedule); however, the resulting model may be adapted to any of the remaining functional categories.

The two major assumptions underlying primary event scheduling problems are: (1) the major maintenance schedule is known, and thus, operational asset availability is also known, and (2) the primary events are commitments that are fixed in start time and duration. The problem then becomes one of optimally assigning operational assets to satisfy primary event requirements.

C. MEASURES OF EFFECTIVENESS (MOEs)

Optimization implies the existence of a measurable criterion that is to be maximized or minimized. In the overall employment scheduling problem the stated objective is to "maintain the highest level of readiness." In recognition of the fact that readiness is a difficult entity to measure, Navy policy defines the following as significant factors supporting fleet readiness: effective deployment of forces, maintenance, training, and personnel morale.

In the broad sense, effective deployment of forces means satisfying the primary event requirements. Decisions to commit forces to operations and exercises at home and abroad are made at the highest levels with careful consideration for their contribution to overall military readiness. Thus, effective deployment of forces is accomplished by prescribing the primary event requirements, in terms of force composition and capability, which are then converted to problem constraints. These constraints must be satisfied at the sacrifice of the remaining factors.

The remaining three major factors, maintenance, training, and personnel morale, are difficult to measure directly, and hence, more concrete MOEs that provide the opportunity to achieve these criteria are sought. The CINCLANTFLT scheduling policies described earlier in this chapter are guidelines or goals designed to maximize the opportunity for each unit to achieve the highest degree of readiness in maintenance, training, and personnel morale.

During the operational phase, CINCLANTFLT policy states that 20 working days per quarter should be assigned for maintenance upkeep. For the CPSKED problem, this implies that at least one third of the home fleet time should be reserved for in-port upkeep.

To maintain training readiness, CINCLANTFLT policy states that ten days per quarter should be provided for each ship to conduct individual ship training (ISE). ISE periods are considered secondary events and not scheduled in CPSKED; however, the CPSKED solution should reserve sufficient home fleet at-sea time to satisfy this requirement.

The major factors affecting personnel morale are family separation and crew liberty. To ensure family separation is not excessive and crew liberty is adequate, CINCLANTFLT policy establishes the following guidelines: no more than one third of the time between overhauls should be deployed time; deployments will be followed by a post deployment leave period; and ships in the operational phase should be scheduled for no more than 30 days at-sea per quarter.

A schedule that provides the optimal amount of home port time for training, morale, and maintenance, the optimal amount of home fleet underway exercise time for training, and an equitable deployment rotation of ships will provide the best opportunity to achieve the CINCLANTFLT goals for readiness. Based on this observation, a measurable MOE can be constructed from the CINCLANTFLT policy guidelines.

The approach is a *goal – programming* technique. Policy statements are used to derive ideal *target* times, or goals, for deployment time, home fleet at-sea time, and deployment rotation time. Home fleet time consists of the operational phase time less deployment time. Home port time is the home fleet time less the home fleet at-sea time. Assuming all constraints can be satisfied, the objective becomes: minimize the deviations from the ideal target times and the single MOE is a function of the deviations from the target times. If some of the constraints cannot be satisfied, constraint violation penalties, discussed in the next chapter, are included in the objective.

This objective captures the intent of the CINCLANTFLT policy guidelines; however, it cannot measure many of the intangible factors that must be considered when developing an employment schedule. Neither can the intangible factors always be included as problem constraints. On the other hand, a human scheduler cannot possibly evaluate all scheduling alternatives to determine an optimum schedule. A human scheduler is required to ensure "all" criteria are satisfied; the optimization model is required to ensure the resulting schedule is the "best" schedule in terms of the established criteria.

The CPSKED problem may now be stated as follows: Generate an annual planning schedule for all carriers and surface combatants that minimizes the deviations from the fleet's ideal schedule (specified by target deployment time, home fleet at-sea time, and deployment rotation time) while satisfying, as best possible, all primary event requirements.

III. MODEL DESCRIPTION

This chapter presents the rationale for modeling the CPSKED problem as a set covering problem. The set covering model and generalizations are discussed and the CPSKED model is developed as an elastic set covering model. The objective function costs and penalties are developed in terms of the CINCLANTFLT policy described in the previous chapter.

A. MODEL SELECTION

Many types of scheduling problems may be solved as set covering or set partitioning problems. The basic formulation is straightforward; however, for practical problems, these formulations typically result in thousands of variables and are considered difficult to solve optimally. For this reason, approximate heuristic methods have been used extensively in solving these problems. Fortunately, a sophisticated large-scale mixed integer linear programming solver, the X System [Ref. 9], permits the efficient solution of many large-scale problems. Bausch [Ref. 3] employed the X System on test problems consisting of several hundred constraints and thousands of variables in his survey of computational techniques for solving large-scale set covering problems; the results were quite favorable. The crude oil tanker problem, Brown, Graves, and Ronen [Ref. 4], in which columns represent possible ship routes and the object is to select the least cost set of routes, contained thousands of variables and was solved using the X System in less than one minute of IBM 3033 CPU time.

Official Navy policy states that "The optimized peacetime employment schedule which has as its objective maximizing combat readiness should always be the goal and guide." [Ref. 1] Thus schedule optimization is a Navy goal. The existence of a sophisticated, proven, large-scale solver allows formulation of the CPSKED problem as a set covering problem with high expectation of achieving optimal solutions.

B. THE SET COVERING MODEL

Set covering models formulated as integer linear programs have been known and proposed for practical applications for many years. The standard formulation is:

$$\min \sum_{j=1}^{J} c_j x_j$$

$$\text{s.t.} \sum_{j=1}^{J} a_{ij} x_j \geqslant b_i \qquad i = 1, \ldots, I$$

$$x_j \in \{0,1\} \quad j = 1, \ldots, J$$

where

$a_{ij} \in \{0,1\}$, and $b_i > 0$ and integer.

In this formulation, a minimum cost set of columns from the constraint matrix must be chosen such that that each constraint is satisfied, i.e., "covered" at least b_i times.

In many practical applications, the columns may be partitioned into sets where only one column per set is allowed. For example, a set may consist of all possible schedules for a single ship and exactly one of the schedules in the set must be selected. If there are K such sets, $S_1, \ldots, S_K$, the model may be generalized to admit only one column per set in the final solution. This is accomplished by adding the following constraints:

$$\sum_{j=1}^{J} \delta_{kj} x_j = 1 \quad k = 1, \ldots, K$$

where

$$\delta_{kj} = \begin{cases} 1 & \text{if } j \in S_k \\ 0 & \text{otherwise.} \end{cases}$$

The standard formulation may be generalized to admit ranges on the constraints. This generalized set covering problem is:

$$\min \sum_{j=1}^{J} c_j x_j$$

$$\text{s.t.} \sum_{j=1}^{J} \delta_{kj} x_j = 1 \qquad k = 1, \ldots, K$$

$$b_i^- \leqslant \sum_{j=1}^{J} a_{ij} x_j \leqslant b_i^+ \quad i = 1, \ldots, I$$

where

$$b_i^+ \geqslant b_i^- > 0.$$

Note that equality constrained set covering problems, i.e., set partitioning problems, can be formulated this way by setting $b_i^+ = b_i^-$ for all i.

Efficient, reliable solution of set covering models is difficult. The X System is an advanced general purpose large-scale optimization system with special features for solving integer and mixed-integer models. This system employs "elastic" programming techniques [Ref. 10]. Elastic programming assumes that all constraints may be violated at a cost. This technique allows the feasible region to be "stretched," subject to penalty costs, and generally results in more rapid convergence to an optimal integer solution. In an elastic formulation, feasible solutions always exist; the objective, then, is to find a feasible solution that minimizes both the original objective and the sum of the elastic penalties.

The elastic formulation of the generalized set-covering problem is:

$$\min \sum_{j=1}^{J} c_j x_j + \sum_{k=1}^{K} (p_k^- s_k^- + p_k^+ s_k^-) + \sum_{i=1}^{I} (p_i^- s_i^- + p_i^+ s_i^+)$$

$$\text{s. t.} \quad 1 - s_k^- \leqslant \sum_{j=1}^{J} \delta_{kj} x_j \leqslant 1 + s_k^+ \qquad k = 1, \ldots, K.$$

$$b_i^- - s_i^- \leqslant \sum_{j=1}^{J} a_{ij} x_j \leqslant b_i^+ + s_i^+ \qquad i = 1, \ldots, I.$$

$$x_j \in \{0,1\} \qquad j = 1, \ldots, J$$

$$s_k^- \geqslant 0, \; s_k^+ \geqslant 0, \text{ and integer} \qquad k = 1, \ldots, K$$

$$s_i^- \geqslant 0, \; s_i^+ \geqslant 0, \text{ and integer.} \qquad i = 1, \ldots, I$$

where

p_k^+, p_i^+ = upper constraint violation penalties

p_k^-, p_i^- = lower constraint violation penalties

b_i^+ = upper constraint limit

b_i^- = lower constraint limit.

C. CPSKED PROBLEM FORMULATION

The CPSKED problem is formulated as a generalized elastic set covering problem using the following notation:

Indicies:

$k = 1, \ldots, K$	(rows) constraints requiring that one schedule column be selected for each ship,
$i = 1, \ldots, I$	(rows) event/ship-type requirements,
$l = 1, \ldots, L$	(rows) event/ weapon system capability requirements,

$j = 1, \ldots, J$	(columns) each representing an individual ship schedule,
$p = 1, \ldots, P$	primary schedule events,
$q = 1, \ldots, Q$	ship-types,
$w = 1, \ldots, W$	weapon system types,
S_k	index set identifying all schedule columns belonging to ship k,
R_p	index set identifying all event/ship-type requirements belonging to event p,
R_q	index set identifying all event/ship-type requirements requiring ship-type q,
V_p	index set identifying all weapon system capability requirements belonging for event p
V_w	index set identifying all weapon system capability requirements requiring weapon system type w.

Data:

$c_j,\ j \in S_k$	cost of schedule j for ship k.
$\delta_{kj},\ j \in S_k,\ k = 1, \ldots, K$	1 if schedule j is for ship k; 0 otherwise,
$a_{ij},\ j \in S_k,\ i \in R_p \bigcap R_q$	1 if schedule j assigns ship k to event p as ship-type q; 0 otherwise,
$\lambda_{lj},\ j \in S_k,\ l \in V_p \bigcap V_w$	1 if ship k has weapon system w; 0 otherwise,
$b_i^-,\ i \in R_p \bigcap R_q$	minimum number of ships of type q required for event p,

$b_i^+, \; i \in R_p \cap R_q$	maximum number of ships of type q allowed for event p,
$b_l^-, \; l \in V_p \cap V_w$	minimum number of weapon systems of type w required for event p,
$b_l^+, \; l \in V_p \cap V_w$	maximum number of weapon systems of type w allowed for event p,
$p_k^-, \; k = 1, \ldots, K$	penalty for not scheduling ship k,
$p_k^+, \; k = 1, \ldots, K$	penalty for assigning more than one schedule to ship k,
$p_i^-, \; i \in R_p \cap R_q$	per unit penalty for assigning too few ships of type q to event p,
$p_i^+, \; i \in R_p \cap R_q$	per unit penalty for assigning too many ships of type q to event p,
$p_l^-, \; l \in V_p \cap V_w$	per unit penalty for assigning too few weapon systems of type w to event p,
$p_l^+, \; l \in V_p \cap V_w$	per unit penalty for assigning too many weapon systems of type w to event p.

Decision Variable:

x_j	1 if schedule j is selected; 0 otherwise.

Logical Variables:

$s_k^+, \;\; k = 1, \ldots, K$	greater than 1 if more than one schedule is selected for ship k; 0 otherwise,
$s_k^-, \;\; k = 1, \ldots, K$	1 if no schedule is selected for ship k; 0 otherwise,
$s_i^+, \;\; i = 1, \ldots, I$	amount by which b_i^+ is violated,

$s_i^-, \; i=1, \ldots, I$	amount by which b_i^- is violated,
$s_l^+, \; l=1, \ldots, L$	amount by which b_l^+ is violated,
$s_l^-, \; l=1, \ldots, L$	amount by which b_l^- is violated.

Formulation:

$$\min \sum_{j=1}^{J} c_j x_j + \sum_{k=1}^{K} (p_k^- s_k^- + p_k^+ s_k^+) + \sum_{i=1}^{I} (p_i^- s_i^- + p_i^+ s_i^+) + \sum_{l=1}^{L} (p_l^- s_l^- + p_l^+ s_l^+)$$

$$\text{s. t.} \quad 1 - s_k^- \leqslant \sum_{j=1}^{J} \delta_{kj} x_j \leqslant 1 + s_k^+ \qquad k=1, \ldots, K$$

$$b_i^- - s_i^- \leqslant \sum_{j=1}^{J} a_{ij} x_j \leqslant b_i^+ + s_i^+ \qquad i=1, \ldots, I$$

$$b_l^- - s_l^- \leqslant \sum_{j=1}^{J} \lambda_{lj} x_j \leqslant b_l^+ + s_l^+ \qquad l=1, \ldots, L$$

$$x_j \in \{0,1\} \qquad j=1, \ldots, J$$

In words, the model is interpreted as: "Choose the minimum cost set of ship schedules such that one schedule per ship is included in the set and most (ideally all) event requirements are satisfied." To produce meaningful planning schedules, the costs and penalty structures are critical to the model. These topics are the subject of the next two sections.

D. SCHEDULE COSTS

This section details the computation of the costs for individual ship schedules, i.e., the c_j values of the CPSKED model. The objective for the CPSKED model is to satisfy the event requirements while providing an equitable rotation of the ships between deployed and home fleet status and providing an even distribution of the home fleet workload. This objective is decomposed into the following three components based on CINCLANTFLT policy goals:

1. Achieve an ideal time between successive deployments for an individual ship.
2. Maintain an ideal ratio of a ship's deployment time to between overhaul time.
3. Maintain an ideal ratio of a ship's home fleet sea time to home fleet total time.

The first two objectives replace the "equitable rotation" requirement while the third replaces the "even workload" requirement.

Under the model assumptions, an employment schedule that satisfies the event requirements while achieving the ideal times and ratios specified is considered an ideal schedule. Given the ship assets and event requirements for the Atlantic fleet, the likelihood of achieving an ideal schedule is extremely small. To obtain a schedule as close as possible to the ideal, a cost structure measuring the deviations from the ideal schedule is imposed on the problem. The following targets are established for all ships:

T_1	time (in days) between deployments,
r_2	target ratio of deployed days to between overhaul days,
T_2	deployment time (in days) required to achieve ratio r_2,
r_3	target ratio of home fleet sea days to total home fleet days.
T_3	home fleet sea time (in days) required to achieve ratio r_3

Costs C_{1j}, C_{2j}, and C_{3j} with respect to a particular schedule j are then defined in terms of the targets as follows:

$$C_{1j} = \begin{cases} 0.1 \times (\text{ deviation above } T_1) \\ 1.0 \times (\text{ deviation below } T_1), \end{cases}$$

$$C_{2j} = \begin{cases} 1.0 \times (\text{ deviation above } T_2) \\ 0.1 \times (\text{ deviation below } T_2), \end{cases}$$

$$C_{3j} = \begin{cases} 1.0 \times (\text{ deviation above } T_3) \\ 0.25 \times (\text{ deviation below } T_3). \end{cases}$$

The costs here are functions of deviation in days from the target. In terms of CINCLANTFLT policy, it is more costly to over-employ a unit rather than under-employ a unit. Consequently, costs are relatively reduced when they reflect under-employment of a unit, i.e., more time between deployments, less deployed time, or less home fleet sea time.

The *linear cost* of a schedule j is defined to be the sum of the three cost functions :

$$C_j = C_{1j} + C_{2j} + C_{3j}.$$

This column cost is intuitively appealing since it can be viewed as a measure of the total deviation in days from an ideal schedule for a particular ship. The sum of the linear costs over all ships indicates a measure of the deviation in days for the fleet employment schedule from an ideal schedule.

Frequently there will be insufficient assets of a given ship-type to satisfy the event requirements. When this occurs, ships of a different type are generally substituted to satisfy the shortfall. The acceptability of ship substitutions depends on the mission requirements for the given event. In this model, substitutions are allowed at an increased cost. Acceptable substitutions are part of the event input data, e.g., for a given event it may be acceptable to substitute an FFG for a DDG with an acceptability factor of 0.8. The acceptability factor is a measure of how well the substituting ship can perform the duties of the required ship for the particular event and lies in the range (0,1]. The acceptability factor is used to adjust the linear cost of a schedule column containing substitution assignments. If there are no substitutions, the acceptability factor is considered to be 1.0 and the linear cost for the column is as described above. If there are substitutions, then the linear column cost is divided by the average of the acceptability factors for the events contained in the schedule column. Then, for two similar columns, one with substitutions and one without, the costs of the column with substitutions will be greater with the amount of the difference a function of the acceptability of the substitution. This procedure allows the model to discriminate between substitutions and primary assets and keeps substitutions to a minimum level.

Though appealing, the linear cost, adjusted for substitutions, may result in poor decisions if used directly in the model. The problem is illustrated by the following example:

> Suppose ships A and B have schedules with costs of 50 and 50 respectively. If ship A and B also have schedule columns with costs 0 and 100 respectively which satisfy the same combined set of event requirements, then the model will not differentiate a preference between the first cover (cost 100) or the second cover (cost 100). Part of the scheduling objective is to distribute the workload equitably over all fleet assets, hence, when costs are equal, the model should be capable of selecting the cover that distributes the costs over the most ships.

To avoid this problem, the squares of the adjusted linear costs are used in the model. This cost allows the model to resolve ties by spreading the cost over the greater number of ships.

All components of a ship's column cost are computed with regard to the ship's current employment cycle. This requires a knowledge of the following historical information for each ship:

D_1	total days in the current operational phase,
D_2	total deployed days in the current operational phase,
D_3	total home fleet sea days in the current operational phase,
D_4	last deployment completion date.

The cutoff date for this information is the last day prior to the model planning period. If a ship has not deployed since beginning its operational phase, its last deployment completion date is set to the date the ship last completed overhaul or was commissioned.

Column cost computation is described in the following equations:

Terms:

c_j	model column cost,
C_j	linear column cost,
C_{1j}	time between deployment cost,
C_{2j}	deployment cost,
C_{3j}	home fleet sea cost,
α_{ij}	substitution acceptability factor,
$\overline{\alpha}_j$	column average acceptability factor,
t_1	time between deployments,
t_{2i}	deploy time for event i,
t_{3i}	home fleet sea time for event i,
T_1	time between deployment target,
T_2	deploy time target,
T_3	home fleet sea time target,
τ_2	deploy time target ratio,
τ_3	home fleet sea time target ratio,
D_1	starting total days in operational phase,
D_2	starting total deployed days,
D_3	starting total home fleet sea days,
D_4	last deployment completion date,

d_1	total days in operational phase,
d_2	total deployed days,
d_3	total home fleet sea days,
d_4	last deployment completion date,

N	ship non-operational days for the planning period (generally overhaul periods),
X	slack operating days for ship-type training and individual ship exercises.

Counters:

$$d_1 = D_1 + 365 - N$$

$$d_2 = D_2 + t_{2i}$$

$$d_3 = D_3 + t_{3i} \ .$$

Targets:

$$T_1 = 360 \quad \text{(may be varied for each ship-type)}$$

$$T_2 = \tau_2 d_1$$

$$T_3 = \tau_3(d_1 - d_2) \ .$$

Cost formulas:

$$C_{1j} = \begin{cases} 0.1(T_1 - t_1) & \text{if } T_1 \geqslant t_1, \\ t_1 - T_1 & \text{if } T_1 < t_1, \\ 0 & \text{if event is in progress at the beginning} \\ & \text{of the planning period.} \end{cases}$$

$$C_{2j} = \begin{cases} T_2 - d_2 & \text{if } T_2 \geqslant d_2, \\ 0.1(d_2 - T_2) & \text{if } T_2 < d_2. \end{cases}$$

$$C_{3j} = \begin{cases} T_3 - d_3 & \text{if } T_3 \geqslant d_3, \\ 0.25(d_3 - T_3) & \text{if } T_3 < d_3. \end{cases}$$

$$\overline{\alpha}_j = \sum_{i : a_{ij} \neq 0} \alpha_{ij} \ / \ \sum_i a_{ij}$$

$$C_j = (C_{1j} + C_{2j} + C_{3j}) \ / \ \overline{\alpha}_j$$

$$c_j = C_j^2$$

E. PENALTIES

In the elastic formulation of the model, penalties can be categorized as either model disruption penalties or goal violation penalties. When violation of an inelastic constraint has no physical interpretation, the penalty for violating the constraint is a model disruption penalty; these penalties should be sufficiently small to allow reasonable relaxation of the feasible region, yet great enough to enforce the constraint in the final solution. When a constraint can be violated at a cost in the final solution, the constraint is actually a goal and the penalty is a goal violation penalty.

In the CPSKED problem, the first set of constraints require that exactly one schedule column be selected for each ship. The second set of constraints requires that.the correct force composition be assigned for each event. The third set of constraints requires that correct set of weapon system capabilities is assigned for each event. The associated ranges and penalties for these sets of constraints are assessed separately.

1. Ship-Schedule Constraints

Since exactly one schedule is desired for each ship, the upper and lower ranges on the ship-schedule constraints are both set to one. Violation of the upper range implies that a ship would receive more than one schedule for the planning period. A ship cannot be employed in different locations simultaneously; hence, the upper range must not be violated in the final solution. The penalty then is a model disruption penalty that increases problem elasticity while enforcing the upper range on the constraint. A ship schedule cost is measured in terms of days deviation from an ideal ship schedule. Schedule costs beyond a certain limit, typically 200-300 days deviation, would be counterproductive to maintaining a high state of combat readiness. An upper bound on this limit of 1000 days deviation is used to establish the model disruption penalty. The CPSKED objective function is in terms of days deviation squared, thus the penalties must also be in days deviation squared and the resulting penalty is 1.0×10^6 days deviation squared. Any combination of columns for a particular ship will cost more, including penalty, than any single column for the ship and consequently, multiple schedules will not be selected in any optimal solution.

Violation of the lower range on a ship-schedule constraint corresponds to not scheduling that ship. The lower penalty, then, should be the price at which it is acceptable to allow the ship to remain idle throughout the planning period. In the CPSKED model, the "idle" price is computed for each ship, this price is equivalent to the column cost for a "do nothing" column. The "idle" price squared is then used as the penalty for violating the lower range of the ship-schedule constraints.

2. Event Requirement Constraints

In the CPSKED model, the events are CINCLANTFLT commitments and the event requirement constraints can be interpreted as goals to meet those commitments. It may not be possible to meet these goals at any reasonable cost. The penalties associated with these constraints are goal violation penalties.

The lower range b_i^- on an event requirement constraint corresponds to the minimum number of ships of a particular type required for the event. Event values are assumed to be related to the event duration and deployment status. Generally, short home fleet sea events are more easily canceled or rescheduled than long duration deployed events and consequently receive a lesser value in the schedule planning process. In the CPSKED model the event values are defined to be the duration of the home fleet sea days and/or the deployed days contained in the event. The lower penalty p_i^- is a price above which the cost of committing additional assets to the event exceeds the value of the contribution of those assets. In this model, the lower penalty is a function of the event value and may be adjusted within the program.

Situations arise where a ship would be under-employed if all minimum event requirements b_i^- are met exactly. Under these circumstances, it may be desirable to schedule the ship for some events in excess of minimum event requirements in order to maintain training and proficiency for the ship. To allow for this possibility, the upper range b_i^+ for all event requirements may be set above the minimum requirement. In most instances, ship assets will be in short supply and the lower range will be binding. The upper penalty p_i^+, in effect when the upper range is exceeded, is a function of the event value and may be adjusted within the program.

3. Force Weapon System Capability Constraints

Frequently, primary events may require a specified set of force weapon system capabilities. Weapon system capabilities are not necessarily unique to ship types and hence, the force system capability requirements may be satisfied by various mixes of ships. Penalties for violating these constraints are related to the additional value a particular weapon system contributes to an event's mission and consequently should be input data under the scheduler's control. These penalties should be high enough to enforce the constraints but less than event/ship-type penalties since a weapon system contributes less than an entire unit to the event's mission. In this prototypic implementation, these penalties were all set to 1,000 (lower) and 0 (upper). These penalties worked well in the model; however, a more thorough knowledge of mission requirements and system contributions would enable improvements.

IV. PROBLEM GENERATION

Solving the CPSKED problem consists of four steps; problem formulation, problem generation, problem solving, and report writing. In this chapter, the second step, problem generation is discussed. In the set covering formulation each of the variables represents a candidate schedule. A primary advantage of this formulation is that only those schedules that are viable need be included in the problem, e.g., time restrictions, cost limits and other real-world constraints may be used in the problem generator to reduce the size of the problem sent to the solver. In a complete set covering problem with m inequality constraints, there are $2^m - 1$ variables or columns. Complete set covering problems rapidly become very large and consequently become difficult or impossible to solve even with the best of solvers. In practical applications, many columns in the complete set will have no usable real-world interpretation with respect to the application. Other columns may violate restrictions on time, speed, distance, costs, etc. To reduce the size of the problem that is ultimately sent to the solver, the column generator should incorporate as much of the column feasibility criteria and real-world restrictions as possible. In the following sections, the techniques used to generate the CPSKED columns are discussed. Since there is a one-to-one correspondence between ship schedules and model columns, the terms "schedule" and "column" are used interchangeably.

A. GENERATING FEASIBLE SCHEDULES

The following three rules are used to determine whether or not a schedule for a particular ship is feasible:

Rule 1. A unit must be of the proper type, or an allowable substitute, to satisfy an event requirement constraint.

Rule 2. A unit may not participate in primary events when the unit is in a non-operational status.

Rule 3. A unit cannot be participate in more than one primary event at any given time.

These rules are used to generate all feasible ship schedule as follows:

For each ship k perform the following steps:

Step 1. Determine the ship-type q and, using rule 1, select all event requirement constraints that demand type q units or allow type q units as substitutions. This "potential ship-event list" is the list of events that ship k could potentially participate in.

Step 2. Determine the ship non-operational periods from input data and, using rule 2, compute the time intersection of each event in the "potential ship-event list" with the non-operational periods. If the time intersection is not null, delete the event from the "potential ship-event list." The resulting list is the "ship-event list."

Step 3. Construct a schedule network as follows: Define a starting node, s, and connect this node to all events in the ship-event list. Using rule 3, connect additional arcs between event pairs if the time intersection of the events in the pair is null; the direction of the arc is from the earlier event to the later event.

Step 4. Let v correspond to an event in a schedule, the set of all directed $s-v$ paths for all v in the network corresponds to the set of all feasible schedules for the ship. Enumerate each $s-v$ path j and set column coefficients: (a) $a_{ij}=1$ if i is on the $s-v$ path; (b) $\delta_{kj}=1$; (c) $\lambda_{lj}=1$ if ship k satisfies part of event/weapon system capability requirement l; and (d) 0 otherwise.

In the CPSKED column generation program, event requirement inputs may be specified by either ship-type or ship hull number. When a scheduler knows *a priori* that a ship must participate in a certain event, the requirement should be input by hull number. The column generator then forces all columns for that hull number to contain the event. Additionally, if a type requirement demands

n units and all n units are specified by hull number, then only those units will contain the event in their ship-event network, i.e., only those units will be considered for satisfying the event/ship-type requirement. Thus column reductions will occur if all units for a specific type requirement are specified by hull number. This is equivalent to fixing assignments in the schedule. Events in progress at the beginning of the planning period should be fixed in this manner. Also, any requirements that must be satisfied by a particular unit should be fixed to ensure the desired results and to reduce the size of the problem.

The CPSKED column generator allows ship-type substitutions to be specified, at a cost, for each type requirement. If there are n of the required ship-type and m of the substitution ship-type, then there will be $n+m$ candidates available to satisfy the requirement, and a consequential increase in the number of columns. Allowable substitutions should be used sparingly and only where tactically feasible, e.g., a carrier would never substitute for a frigate and a frigate would probably never substitute for a cruiser. Substitution strategy may have a dramatic effect on the number of feasible columns generated.

B. COLUMN REDUCTION

The number of columns produced by the method described above is much less than the 2^I-1 combinations which would be produced by a naive generator. Nevertheless, the number of columns can grow very large. Many of these columns may correspond to unit schedules that are unacceptable because of excessive cost. Excessive cost corresponds to severe over-employment of the unit and is counterproductive to the maintenance of high fleet readiness.

After each schedule column is generated, a cost for that column is computed. The cost represents a measure of the deviation from the ideal individual ship schedule. For each of the component costs, limits may be established beyond which the schedule is deemed completely unacceptable. If the cost of a column exceeds these limits, it is not included in the problem. The CPSKED column generation program accepts the following limiting parameters by ship-type:

Maximum home fleet sea cost,
Maximum deployment cost,
Maximum time between deployment cost,
Maximum column cost.

If an event requires a specific ship by hull number, then that event becomes mandatory for the ship; the cost limits are ignored for the column that contains only mandatory events. Significant reductions in the number of columns sent to the solver are possible using this cost limiting approach.

V. IMPLEMENTATION AND RESULTS

The CPSKED model has been implemented at the Naval Postgraduate School. Input data for testing this implementation has been extracted from the Atlantic Fleet projected annual schedule for calendar year 1983. The testing results indicate that high quality schedules are produced efficiently. Schedule quality is based on comparisons of the CPSKED schedule and the CINCLANTFLT schedule. Model efficiency is discussed in terms of computational experience based on four model runs.

A. COMPUTER PROGRAMS

The CPSKED model has been implemented on an IBM 3033 AP computer system under the CMS operating system. CPSKED consists of three parts; the column generator, the solver, and the report writer.

1. Problem Generator

The CPSKED problem generator is written in ANSI standard FORTRAN 77 and compiled by IBM VS FORTRAN. The program uses a Ship Data file and an Event Data file for input. The program produces an unformatted file which is read directly by the solution driver; this file represents the CPSKED problem in a compact data format suggested by Bausch [Ref. 3].

2. Problem Solver

The solver consists of a problem driver, XSCOVC, and several subroutines. The X System solver routines are written in Level 66 FORTRAN and compiled by the IBM FORTRAN IV H (Extended) compiler. The solver employs many advanced features including hypersparse data representation, complete constructive degeneracy resolution, basis factorization, and elastic range constraints. The X System may be tailored to specific models to form the computational foundation for specialized application packages. In this development, the CPSKED programs have not been integrated with the solver to take full advantage of the solver's capabilities. In the CPSKED implementation, the solver generates a compact data file representing the CPSKED solution; this file is used as an input file to the CPSKED report writer. The driver, XSCOVC, also produces a condensed output report containing solution characteristics and computational statistics for the problem solution.

3. Report Writer

The CPSKED report writer is written in ANSI standard FORTRAN 77. The program uses the Ship Data file, Event Data file, and schedule solution file as inputs and produces the following reports:

Ship Statistic Report;
Ship Schedules Report;
Event Force Assignment Report.

Samples of the input data files and the CPSKED reports are included in the Appendices.

B. TEST DATA

The model has been tested using actual data from the Atlantic Fleet for calendar year 1983. Model input consists of a ship data input file and an event data input file. Sample input data files are included as Appendices A and B. Scheduling parameters, or goals, are set within the column generation program.

1. Ship Data

The Atlantic Fleet carrier and surface combatant assets for the calendar year 1983 consisted of the ships listed in Table 1.

TABLE 1

1983 Atlantic Fleet Combatants

	Type	Number
Aircraft Carriers	CV/CVN	9
Guided Missile Cruisers	CG/CGN	14
Guided Missile Destroyers	DDG	23
Destroyers	DD	17
Guided Missile Frigates	FFG	19
Frigates	FF	29
Total		111

Non-operational periods, overhaul etc., and historical data for these assets are known and included in the ship input data file. The requirement to select exactly one schedule for each ships results in 111 schedule selection constraints.

2. Event Data

All extended operations and major exercises involving surface combatant units were extracted from the CINCLANTFLT annual schedule resulting in the event list displayed in Table 2.

A primary event is composed of a collection of sub-events; each of these sub events corresponds to an employment term (EMPTERM) used in the Atlantic Fleet Schedule. Each sub-event is designated as deployed time, home fleet sea time, or home fleet inport time. The primary event, MED 2-83, is used as an example, see Table 3.

TABLE 2.

1983 Primary Event List

Extended Operations	Major Exercises
MED 1-83	COMPTUEX 2-83
IO 1-83	SOLID SHIELD 83
MEF 1-83	OCEAN SAFARI 83
MEF 2-83	COMPTUEX 3-83
SNFL 1-83	COMPTUEX 4-83
IO 2-83	COMPTUEX 1-84
MED 2-83	
MEF 3-83	
SNFL 2-83	
UNITAS	
MEF 4-83	
MED 1-84	

(listed in order of event start time)

TABLE 3.

MED 2-83 Sub-events

	EMPTERM	START	END	CODE
Primary event:	MED 2-83	069	355	
Sub-events:	EXER (Readex 1-83)	069	092	S
	POM	093	122	I
	ENR (Transit)	123	133	D
	OPCON	134	315	D
	ENR (Transit)	316	325	D
	LVUPK (Stand down)	326	355	I

codes: D - Deployed time,
I - Home fleet in port time,
S - Home fleet sea time.

A primary event requires a specific force composition, with possible allowance for substitution of assets. These requirements result in the event/ship-type constraints. Typical requirements, based on the MED 2-83 example, are listed in Table 4.

TABLE 4.

MED 2-83 Ship-Type Requirements

Type	Hull	Substitution	Number
CV/CVN	69	none	1
CG/CGN	any	DDG, $\alpha = 0.7$	2
DDG	any	DD, $\alpha = 0.8$	2
DD	any	none	2
FFG	any	FF, $\alpha = 0.7$	3
FF	any	none	3

Force weapon system capability requirements are based on current requirements for forces deploying to the Mediterranean, Middle East, and Indian Ocean. Typical requirements using the MED 2-83 example are listed in Table 5.

TABLE 5.

MED 2-83 Capability Requirements

System	Number
AAW Missile (SM-1/ER)	2
AAW Missile (SM-1/MR)	4
AAW Radar (SPS-48)	3
Data Link (NTDS)	4
Passive Sonar (TASS/TACTAS)	3
ASW Helicopter (LAMPS)	3
Guns (5in/54)	4

The 1983 primary events result in a total of 73 event/ship-type constraints. Force weapon system capability requirements result in 44 additional constraints.

3. Scheduling Parameters

The parameters listed in Table 6 represent the scheduling policy goals and cost limits used in the model runs. These parameters may be modified in the problem generator.

TABLE 6.

Scheduling Parameters

	CV/CVN	CG/CGN	DDG	DD	FFG	FF
T_1	360	360	360	360	360	360
τ_2	.33	.33	.33	.33	.33	.33
τ_3	.33	.33	.33	.33	.33	.33
Max C_1	120	120	120	120	120	120
Max C_2	180	180	120	120	90	90
Max C_3	90	90	60	60	45	45
Max C_j	300	180	150	150	120	120

C. SCHEDULE QUALITY

CPSKED captures the essence of CINCLANTFLT scheduling policy and provides an optimum schedule with respect to that policy. The objective costs, including penalty costs, indicate the overall quality of a schedule, e.g. a schedule with a total objective value of zero is one that satisfies all requirements and exactly achieves all of the CINCLANTFLT policy goals.

The CINCLANTFLT annual schedule did not contain projected ship assignments for all projected primary events, e.g., UNITAS and several exercises were scheduled with ship assignments indicated "DTMD" for "to be determined." To place the CINCLANTFLT schedule on an equal basis with CPSKED for conducting comparisons, all known CINCLANTFLT ship assignments were fixed and CPSKED was run to optimize the remaining part of the schedule. The result is CINCLANTFLT's annual schedule with all "DTMDs" optimally assigned. Table 7 lists the schedule summary data used to compare this CINCLANTFLT schedule to the CPSKED schedule.

TABLE 7.

CINCLANTFLT vs. CPSKED

	CINCLANTFLT	CPSKED	% IMPROVEMENT
-Objectives-			
Cost:	1,472,500	446,700	70%
-Penalties-			
-violations-			
Sched selection:	0	0	0%
Event/Ship-type:	0	0	0%
Weapon Capabilities:	11	9	18%
-Unit Costs-			
-mean (std.dev.)-			
Total (C_j):	48.2(57.3)	42.7(49.0)	11%(14%)
TBD (C_{1j}):	44.9(43.9)	34.7(28.9)	23%(34%)
DEP (C_{2j}):	25.9(40.4)	24.5(40.1)	5%(1%)
SEA (C_{3j}):	3.9(4.4)	2.9(3.3)	26%(25%)
-Unit Statistics-			
TBD (target 360):	329(142)	344(103)	5%(27%)
DEP Ratio (target .33):	.33(.10)	.34(.09)	−3%(10%)
SEA Ratio (target .33):	.30(.06)	.30(.05)	0%(16%)

The CPSKED model reflects a 70% improvement in quality and also violates fewer weapon system capability goals. Average individual unit costs are not only reduced, they are spread more equitably over the ships as indicated by reduced standard deviations.

A model can never capture all of the criteria involved in scheduling navy ships and, consequently, the full magnitude of improvement indicated by this comparison may not be achieved. However, a human scheduler can neither evaluate all of the scheduling combinations considered by the model, nor can he hope to compute measures of effectiveness with any precision. Significant scheduling improvements can be achieved by teaming the human scheduler and the model together.

After making an initial reference run of the model, the human scheduler may add constraints or "what-if" questions to the model by fixing specific event/ship assignments. The model should be run again producing an optimal schedule subject to the newly imposed restrictions. The scheduler must then determine whether the restrictions are justifiable in terms of the increased costs. Thus, inter-run comparisons provide a means for developing optimal schedules and for conducting "what-if" analysis. Geoffrion and Powers remarks on inter-run comparisons with distribution planning models apply here as well.

> It is our repeated observation that the motives for making inter-run comparisons are so overwhelming that, in practice, comparisons ... are made and conclusions drawn even when a heuristic (suboptimal) rather than optimizing procedure is used....The importance of inter-run comparisons should not be underestimated. They are needed to justify conclusions reached with the help of the model by (a) exploring uncertain assumptions, (b) studying the impact of alternative futures, and (c) measuring the performance differences between the leading alternatives. ...If the solver is heuristic in character, such comparisons will be very unreliable because comparing two error-prone solutions greatly magnifies the relative error. [Ref. 2]

The best human schedulers will always produce suboptimal schedules. The quality gap between the CINCLANTFLT and CPSKED schedules indicates considerable room for improvement. Narrowing the gap demands optimization support, such as CPSKED, and results in more efficient utilization of fleet assets.

D. COMPUTATIONAL RESULTS

Computational results are discussed in terms of problem characteristics, problem size, and model execution times. The model was run under the following conditions:

1.	CPSKED(NS)	without substitutions;
2.	CPSKED(SU)	with substitutions and unlimited costs;
3.	CPSKED(S)	with substitutions and cost limits;
4.	CPSKED(CLF)	with CINCLANTFLT fixed assignments.

Run 1, without substitutions, was made to establish a reference objective value and determine if all events could be satisfied without substitution. Run 2, with selected substitutions and no cost limits was made to demonstrate the reduction in problem size that may be achieved by including cost limit constraints in the problem generator. Run 3 was made to demonstrate the effect of allowing ship-type substitutions. Run 4 includes all fixed assignments from the CINCLANTFLT annual schedule. Results of the runs are summarized in Table 8.

1. Characteristics

In each run there are 111 ship-schedule selection constraints, 73 event/ship-type constraints, and 44 force weapon system capability constraints. There are 105 ships operational for some period during the planning year, the remaining 6 ships are not operational at any time during the year. Events in progress at the beginning of the year and carrier participation in extended operations are fixed assignments in all runs.

2. Problem Size

Problem size in terms of the number of columns and non-zero elements sent to the solver is a function of the number of substitutions allowed, the number of assignments fixed, the total number of constraints, and the cost limits imposed in the problem generator.

TABLE 8.

CPSKED Results

	Run 1 CPSKED(NS)	Run 2 CPSKED(SU)	Run 3 CPSKED(S)	Run 4 CPSKED(CLF)
-*Characteristics*-				
Total Ships:	111	111	111	111
Operational Ships:	105	105	105	105
Total Events:	19	19	19	19
Allowed Subs:	no	yes	yes	yes
Cost Limits:	yes	no	yes	yes
-*Objectives*-				
cost:	395,200	427,000	446,700	1,472,500
-*Penalties*-				
Schedule Selection:	0	0	0	0
Event/Ship-type:	4,144,000	0	0	0
Weapon Capability:	10,000	7,000	9,000	11,000
Total:	4,549,200	434,000	455,700	1,483,500
-*Problem Size*-				
Rows:	228	228	228	228
Columns:	4,109	15,193	10,723	3,984
Non-Zeros:	19,019	84,247	55,404	19,092
-*Run Times*-				
-(in cpu seconds)-				
Generator:	2.3	8.3	6.2	2.4
Solver:	23.0	172.8	113.0	22.6
Reports:	0.6	0.7	0.7	0.7

Substitutions dramatically increase the problem size as indicated by a comparison of runs 1 and 3; however, the event/ship-type penalties observed in run 1 indicate that all requirements could not be satisfied without substitutions. Commitments must be met, and consequently, substitutions are necessary to avoid event/ship-type penalties.

Fixing schedule assignments that are known *a priori* will significantly decrease the problem size; however, fixing assignments can be expected to increase the costs and may increase the number of goal violation penalties. Compare runs 3 and 4.

The number of event/ship-type constraints will influence the number of columns generated because more events are added to the event list used to generate the columns. However, the addition of weapon capability constraints only increases the number of rows in the problem.

The inclusion of cost limits in the problem generator results in a problem size reduction of approximately 30% with little degradation in the cost objective, compare runs 2 and 3.

3. Execution Times

Total execution time for model runs consists of generation time, solution time, and reporting time. To effectively employ CPSKED as a decision support system requires rapid execution. Generation and reporting time are relatively insignificant when compared to solution time. Solution time is influenced by the problem size, problem penalties, and the techniques employed by the solver. The solution times observed in this study compare very favorably with solution times for other large-scale set covering problems. [Refs. 3,4, and 11]

VI. CONCLUSIONS AND RECOMMENDATIONS

This study has demonstrated that optimization techniques can produce high quality annual fleet employment schedules efficiently. Response times are short enough to permit using this model in an interactive schedule planning system. Refinements in the implementation of this model can further reduce solution times.

The CINCLANTFLT versus CPSKED schedule comparisons indicate there is room for improving fleet employment schedules. Optimization models similar to CPSKED can become powerful management tools for developing, refining, and maintaining employment schedules.

An optimization model provides a means for considering "all" alternatives to determine the "best" schedule subject to the constraints supplied to the model. This schedule may then be used as a reference for comparing alternate schedules that may include additional criteria not evident in the initial model run. Because of the relatively fast response times, this process may be conducted iteratively until a final acceptable annual schedule is developed. The optimization model ensures that costs are minimized. The scheduler, or decision maker, must decide whether the additional criteria are justifiable in terms of the resulting increased costs. Thus, the model provides the decision maker with the capability of producing high quality optimum schedules that satisfy, or at least consider, all scheduling criteria.

In its present state of development, the CPSKED implementation is not an end-user product. It does not possess a user-friendly front end and has not been fully integrated with the solver. Input data requirements are extensive and presently require fixed formatted files. An end-user implementation should include an interactive front end for generating event requirement input. The front-end should incorporate "canned" requirements that can be edited for recurring events. The model should also have access to a data base for extracting and updating the ship input data. Integration of the problem generator and the solver can reduce file handling and exploit more of the X System's capabilities to reduce overall execution time.

The model development in this study has focused on scheduling combatants to primary events. The model may be applied to other primary event scheduling problems, e.g., amphibious forces, service forces, etc., by changing the input data files and scheduling parameters.

Navy doctrine states that "The optimized peacetime employment schedule that has as its objective maximizing combat readiness should always be the goal and guide." CPSKED, or a similar optimizing decision support system, can, and should, be used to assist schedulers in achieving that objective.

APPENDIX A

SAMPLE EVENT INPUT DATA

Card Type	Card Columns	Data Description
All	1	Card type M = Major event card S = Sub-event card H = Hull requirement card T = Ship-type requirement card W = Weapon system requirement card N = Hull specification card
M	2-4	Event number
	5-26	Event name
	27-30	Julian start date
	31-34	Julian completion date
S	2	Event code E = Major employment C = Concurrent employment
	3	Status code S = Home fleet at-sea operations D = Deployed operations
	4-12	Employment term (EMPTERM)
	13-28	Location term
	29-43	Supplemental information
	44-63	Remarks
	64-67	Julian start date
	68-71	Julian completion date
H	2-14	Six 2 digit codes indicating the number of ships of types 1 thru 6 required by hull number. For each non-zero field an N card is required.
T	2-13	Six 2 digit codes indicating the number of ships of types 1 thru 6 required by ship-type. Does not include ships required on H card.
W	2-19	Up to nine 2 digit codes indicating the number of weapon systems of types 1 thru 9 required.
N	2-3	2 digit code indicating ship type
	4-39	Up to nine 4 digit ship hull numbers, the number of fields used must correspond with the number indicated on the H card for the corresponding ship type.

ship types	1 = CV/CVN
	2 = CG/CGN
	3 = DDG
	4 = DD
	5 = FFG
	6 = FF
weapon systems	
	1 = AAW missile systems SM1-ER
	2 = AAW missile systems SM1-MR
	3 = AAW Radar system SPS-48
	4 = Data link system NTDS Link-11
	5 = Passive sonar system TASS/TACTAS
	6 = Helo capability LAMPS
	7 = 5"/54 Gun system

```
FILE: EVENTLG  DATA      A1

  EVENTLG (CPSKED)
M001MED 1-83                   30013171
SE OPCON                         CINCUSNAVEUR                                30013130
SCDDEPLOY                                           MED 1-83                 30013140
SE ENR        CONUS                                                          31313140
SE LVUPK                                                                     31413170
H01020201020 5
T000000000000
W020403040303 04
N010067
N0200410040
N0300100037
N040944
N0500080016
N0610981093104310561090
M002IO 1-83                    30013183
SE OPCON                         CINCPACFLT                                  30013143
SCDDEPLOY                                           IO 1-83                  30013153
SE ENR        CONUS                                                          31443153
SE LVUPK                                                                     31543183
H010101000001
T000000000000
W01020002020200
N010066
N020019
N030043
N061044
M003MEF 1-83                   30013105
SE OPCON                         COMIDEASTFOR                                30013064
SCDDEPLOY                                           MEF 1-83                 30013075
SE ENR        CONUS                                                          30653075
SE LVUPK                                                                     30763105
H000001010000
T000000000000
W00000001000100
N030023
N040978
M004MEF 2-83                   30013213
SE POM                                                                       30013030
SESENR        ROTA                                                           30313040
SCDDEPLOY                                           MEF 2-83                 30313254
SE OPCON                         COMIDEASTFOR                                30413245
SE ENR        CONUS                                                          32463254
SE LVUPK                                                                     32553284
H000000010100
T000000000000
W00000001000100
N040963
N050007
M005SNFL 1-83                  30013242
SE ENR                                                                       30013010
SCDDEPLOY                                           SNFL 1-83                30013211
SE OPCON                         STANAVFORLANT                               30103201
SE ENR        CONUS                                                          32023211
SE LVUPK                                                                     32123242
H000000010000
T000000000000
N040974
M006IO 2-83                    30313285
SE POM                                                                       30313061
SE ENR        ROTA                                                           30623071
SCDDEPLOY                                           IO 2-83                  30623255
SE OPCON                         CINCPACFLT                                  30713246
SE ENR        CONUS                                                          32463255
SE LVUPK                                                                     32563285
H010100000000
T000001000001
W01020002020200
X000000690000
N010070
N020039
M007MED 2-83                   30693355
```

```
FILE: EVENTLG  DATA      A1

SESREADEX  CARIBBEAN SEA  01-83                              30693092
SE  POM                                                      30933122
SE  ENR    ROTA                                              31233133
SCDDEPLOY                                MED 2-83            31233325
SE  OPCON                 CINCUSNAVEUR                       31333315
SE  ENR    CONUS                                             33163325
SE  LVUPK                                                    33263355
H010000000000
T000202020303
W02040304030304
X000027383557
N010069
M008COMPTUEX 2-83       30953112
SESCOMPTUEX               02-83                              30953112
H000000000000
T000202020303
M009MEF 3-83            31073303
SE  POM                                                      31073136
SE  ENR    ROTA                                              31373146
SCDDEPLOY                                MEF 3-83            31373273
SE  OPCON                 COMIDEASTFOR                       31473163
SE  ENR    CONUS                                             32643273
SE  LVUPK                                                    32743303
H000000000000
T000000010001
W00000001000100
X000048006800
M010SOLID SHIELD 83     31193131
SESEXER    ATLANTIC OCEAN                SOLID SHIELD 83     31193131
H000000000000
T010202020202
X000027383648
X000000006859
M011SNFL 2-83           31403365
SE  POM                                                      31403170
SE  ENR                                                      31713180
SCDDEPLOY                                SNFL 2-83           31713365
SE  OPCON                 STANAVFORLANT                      31613355
SE  ENR    CONUS                                             33553365
H000000000000
T000001000000
X000000393738
M012OCEAN SAFARI 83     31483198
SESEXER    ATLANTIC OCEAN                UNITED EFFORT       31483157
SESEXER    NORTH ATLANTIC                OCEAN SAFARI 83     31583168
SESEXER    NORTH ATLANTIC                BALTOPS 83          31803188
SESENR     CONUS                                             31893198
H010000000000
T000201020200
X000027383647
N010067
M013COMPTUEX 3-83       31523168
SESCOMPTUEX               03-83                              31523168
H000000000000
T000202020303
M014UNITAS              31523365
SE  POM                                                      31213151
SE  OPCON                 COMSOLANT                          31523344
SCDDEPLOY                                UNITAS - WATC       31523344
SE  LVUPK                                                    33453365
H000000000000
T000001010001
X000049396948
M015MEF 4-83            31663365
SE  POM                                                      31663195
SE  ENR    ROTA                                              31963205
SCDDEPLOY                                MEF 4-83            31963355
SE  OPCON                 COMIDEASTFOR                       32063345
SE  ENR    CONUS                                             33463355
SE  LVUPK                                                    33563365
H000000000000
T000000010001
```

```
FILE: EVENTLG  DATA     A1

W00000001000100
X000048006800
M016COMPTUEX 4-83       32213238
SESCOMPTUEX               04-83                            32213238
H000000000000
T000202020303
M017IO 1-84             32413365
SE POM                                                     32413270
SE ENR      ROTA                                           32713281
SCDDEPLOY                                IO 1-84           32713365
SE OPCON                  CINCPACFLT                       32823365
H000000000000
T000101000001
W01020002020200
X000000376900
M018MED 1-84            32443365
SESREADEX                 02-83                            32443263
SE POM                                                     32643293
SE ENR      ROTA                                           32943303
SCDDEPLOY                                MED 1-84          32943365
SE OPCON                  CINCUSNAVEUR                     33043365
H010000000000
T000202020303
W02040304030304
X000027383547
X000000006900
N010062
M019COMPTUEX 1-84       33343349
SESCOMPTUEX               01-84                            33343349
H000000000000
T000202020303
```

APPENDIX B

SAMPLE SHIP INPUT DATA

Card Column	Data Description
1-2	Ship-type code (1 thru 6)
3-6	Ship-type designation (CV/CVN, CG/CGN, DDG, DD, FFG, FF)
7-10	Ship hull number
11-33	Ship name
34-37	Overhaul or precom start date (current planning period)
38-41	Overhaul or precom completion date
42-45	Non operational start date (except overhaul)
45-48	Non operational completion period
49-52	Total days since last overhaul or commissioning thru the start of the current planning period.
53-56	Total deployed days since last overhaul thru the start of the current planning period.
57-60	Total home fleet operational days since last overhaul thru start of current planning period.
61-64	Total home fleet at-sea days since last overhaul thru start of current planning period.
65-68	Date last deployment completed or last day before planning period is ship is deployed or overhaul completion date or commissioning date.
69-78	weapon system indicators 1=installed, 0=not installed.
ship types	1 = CV/CVN 2 = CG/CGN 3 = DDG 4 = DD 5 = FFG 6 = FF
weapon systems	1 = AAW missile systems SM1-ER 2 = AAW missile systems SM1-MR 3 = AAW Radar system SPS-48 4 = Data link system NTDS Link-11 5 = Passive sonar system TASS/TACTAS 6 = Helo capability LAMPS 7 = 5"/54 Gun system

```
FILE: SHIP     DATA     A1

  LANTFLT COMBATANTS
01CV  0043N00000CORAL SEA      3001336500000000000000000000000033650000000
01CV  0059N03359FORRESTAL      3001336500000000000000000000000033650000000
01CV  0060N03360SARATOGA       3001303030543114000000000000000030300000000
01CV  0062N03362INDEPENDENCE   0000000030323201109504400655019623460000000
01CV  0066N03366AMERICA        0000000031893331062002980322009833650000000
01CV  0067N03367KENNEDY        0000000030013069100004780522015221930000000
01CVN 0068N03368NIMITZ         3168336500000000109503660729021820430000000
01CVN 0069N03369EISENHOWER     0000000000000000109503830712023021930000000
01CVN 0070N20993VINSON C       0000000032553365004200000042000023220000000
02CG  0017N52688YARNELL HE     0000000000000000094003360640018122161011001
02CG  0019N52690DALE           0000000000000000014500500095002823651011001
02CG  0020N52691TURNER RK      3001301500000000000000000000000030151011001
02CG  0026N52701BELKNAP        0000000000000000058501420443009921011011001
02CG  0027N52702DANIELS J      3001327500000000000000000000000032751011001
02CG  0028N52703WAINWRIGHT     0000000000000000000000000000000033651011001
02CG  0034N52709BIDDLE         0000000000000000068503170367010523471011001
02CGN 0036N20541CALIFORNIA     3001313800000000000000000000000031380111011
02CGN 0037N20669SOUTH CAROLINA 3001336500000000000000000000000033650111011
02CGN 0038N20681VIRGINIA       0000000000000000109503370758023021930111011
02CGN 0039N20682TEXAS          3256336500000000109503860709021420430111011
02CGN 0040N20624MISSISSIPPI    3213336500000000096503010664020023650111011
02CGN 0041N20807ARKANSAS       3274336500000000019000500140004123650111011
02CG  0047N00000TICONDEROGA    3001303100000000000000000000000030311011011
03DDG 0002N04668ADAMS CF       3032336500000000000000000000000033650100001
03DDG 0003N04669KING J         3001308700000000000000000000000030870100001
03DDG 0004N04670CLAWRENCE      0000000000000000015800000158006422070100001
03DDG 0005N04671RICKETTS CV    0000000000000000009000000090003022750100001
03DDG 0006N04672BARNEY         3072336500000000103003920638019221940100001
03DDG 0010N04676SAMPSON        0000000000000000018700500137004223650100001
03DDG 0011N04677SELLERS        3001322600000000000000000000000032260100001
03DDG 0017N04683CONYNGHAM      0000000000000000066001690509014820490100001
03DDG 0018N04684SEMMES         3001303700000000000000000000000030370100001
03DDG 0019N04685TATTNALL       0000000000000000003000000050001023350100001
03DDG 0023N04690BYRD RE        0000000000000000027700500227006823650100001
03DDG 0037N52231FARRAGUT       3278336500000000099003430647021123651001001
03DDG 0038N52232LUCE           3001307800000000000000000000000030781001001
03DDG 0039N52233MCDONOUGH      0000000000000000086503170548016523511001001
03DDG 0040N52234COONTZ         3001319000000000000000000000000031901001001
03DDG 0041N52235KING           3001315000000000000000000000000031501001001
03DDG 0042N52236MAHAN          0000000000000000052500000525020012021001001
03DDG 0043N52683DAHLGREN       0000000000000000109503950700021023651001001
03DDG 0044N52684PRATT WV       0000000000000000091503650550016523471001001
03DDG 0045N52685DEWEY          0000000000000000055501530402012121811001001
03DDG 0046N52686PREBLE         3001306700000000000000000000000030671001001
03DDG 0993N21436KIDD           0000000000000000015500000155004222060101011
03DDG 0995N21438SCOTT          3001303000000000000000000000000030300101011
04DD  0944N52203MULLINNIX      3142336500000000034300000343013520220000001
04DD  0963N20574SPRUANCE       3244336500000000048501950290008821950011111
04DD  0968N20588RADFORD AW     0000000000000000018900000189007521760011111
04DD  0969N20589PETERSON       3001310500000000000000000000000031050011111
04DD  0970N20590CARON          3001303800000000000000000000000030380011111
04DD  0974N20600COMTE DE GRASSE3288336500000000109504190675021321010011111
04DD  0977N20603BRISCOE        3001319100000000000000000000000031910011111
04DD  0978N20604STUMP          3192336500000000109503900705021223650011111
04DD  0979N20611CONOLLY        0000000000000000106003240736022520490011111
04DD  0980N20612MOOSBRUGGER    3001312100000000000000000000000031210011111
04DD  0981N20613HANCOCK J      3001328000000000000000000000000032800011111
04DD  0982N20614NICHOLSON      3001309000000000000000000000000030900011111
04DD  0983N20615RODGERS J      3001313500000000000000000000000031350011111
04DD  0987N20834OBANNON        3001307400000000000000000000000030740011111
04DD  0988N20835THORN          3001313000000000000000000000000031300011111
04DD  0997N00000TAYLOR         3001328100000000000000000000000032810011111
04DD  0989N20836DEYO           0000000000000000065001370513015523110011111
05FFG 0004N04695TALBOT         3001316500000000000000000000000031650100010
05FFG 0005N04698PAGE RL        3001336500000000000000000000000033650100010
05FFG 0006N04699FURER JA       0000000000000000046801800288008523480100010
05FFG 0007N21028PERRY DH       0000000000000000073002950435012523550100010
05FFG 0008N21032MCINERNEY      0000000000000000026500500215006623650100010
05FFG 0011N20964CLARK          0000000000000000036501530212006421800100010
05FFG 0013N20966MORISON SE     0000000000000000036501500212007123080100010
05FFG 0015N20968ESTOCIN        0000000000000000031001800130002823480100010
```

1 2 4 5 6 7

```
FILE: SHIP      DATA      A1

05FFG 0016N20969SPRAGUE C          000000000000000022500500175005123650100010
05FFG 0020N20973ANTRIM             000000000000000005000000050002023150100010
05FFG 0021N20974FLATLEY            000000000000000005000000050002023150100010
05FFG 0022N20975FARION             300130690000000000000000000000030690100010
05FFG 0024N20977WILLIAMS J         000000000000000005000000050002023150100010
05FFG 0026N20979GALLERY            000000000000000002000000020001023450100010
05FFG 0028N21053BOONE              300131960000000000000000000000031960100010
05FFG 0029N21054GROVES SW          300132420000000000000000000000032420100010
05FFG 0031N21056STARK              300133650000000000000000000000033650100010
05FFG 0032N21057HALL JL            300132270000000000000000000000032270100010
05FFG 0034N21059FITCH A            300133240000000000000000000000033240100010
06FF  1038N54036MCCLOY             000000000000000090003430547017222340000111
06FF  1040N54037GARCIA             000000000000000005500000055002023100000111
06FF  1043N54039MCDONNELL E        000000000000000019200500142004523650000111
06FF  1044N54040BRUMBY             000000000000000003500000035014520150000111
06FF  1047N54042VOGE               300132550000000000000000000000032550000111
06FF  1049N54044KOELSCH            300132620000000000000000000000032620000111
06FF  1056N54051CONNOLE            000000000000000109503090786024223110000111
06FF  1059N54054SIMS WS            000000000000000093502620673020023130000111
06FF  1061N54056PATTERSON          300131350000000000000000000000031350000111
06FF  1068N54063VREELAND           000000000000000037500000375008013450000111
06FF  1072N54067BLAKELY            316633650000000089803400558015223450000111
06FF  1075N54070TRIPPE             000000000000000060501690436013220490000111
06FF  1078N20049HEWES J            000000000000000026800000268009620970000111
06FF  1079N20050BOWEN              000000000000000048501530332008521800000111
06FF  1080N20051PAUL               300130200000000000000000000000030200000111
06FF  1081N20052AYLWIN             000000000000000050001800320009523450000111
06FF  1082N20053MONTGOMERY E       300132490000000000000000000000032490000111
06FF  1084N20055MCCANDLESS         300133650000000000000000000000033650000111
06FF  1085N20056BEARY CB           000000000000000109503290766028020490000111
06FF  1089N20067BROWN JL           000000000000000109502780817026922180000111
06FF  1090N20068AINSWORTH          327833650000000109502970798022012560000111
06FF  1091N20069MILLER             000000000000000109502950800024011960000111
06FF  1092N20070HART TC            000000000000000109502940801025122180000111
06FF  1093N20071CAPODANNO          322733650000000109503350760022413450000111
06FF  1094N20072PHARRIS            000000000000000109503500725026011960000111
06FF  1095N20073TRUETT             000000000000000101704530564017523450000111
06FF  1096N20074VALDEZ             000000000000000109503340761021521000000111
06FF  1097N20075MOINESTER          000000000000000067701690508014820490000111
06FF  1098N17700GLOVER             000000000000000054001800360010823450000111
```

APPENDIX C

SAMPLE SHIP STATISTICS REPORT

Column Heading	Data Description
Nr.	CPSKED ship number
Hull Nr.	Ship type and hull number
Ship Name	Ship name
Sked Cost	Schedule column cost, C_j
Ship Cost	Ship schedule cost, $C_{1j} + C_{2j} + C_{3j}$ note, this does not include substitution factor.
C1	Time between deployment cost, C_{1j}
C2	Deployment cost, C_{2j}
C3	Home fleet sea cost, C_{3j}
CY Days	Days since last overhaul or commissioning
DEP Days	Deployed days since last overhaul or commissioning
PCT Dep	Percentage of days deployed since last overhaul or commissioning
HOME Days	Home fleet days since last overhaul or commissioning
SEA Days	Home fleet sea days since last overhaul or commissioning
PCT Sea	Percentage of home fleet days spent at sea since last overhaul or commissioning
TBLD	Time between last deployments
Last DEP	Last deployment completion date or last day of planning period if deployed or in overhaul or commissioning or overhaul completion date
	Summary lines include fleet averages and standard deviations. Non-zeros indicate the number of ships used to compute the fleet summary statistics.

```
                 SHIP STATISTICS REPORT
EVENT FILE:  EVENTLG (CFSKED)          SHIP FILE:  LANTFLT COMBATANTS

NR.  HULL       SHIP NAME          SKED   SHIP                            CY      DEP     PCT     HOME    SEA     PCT              LAST
     NR.                           COST   COST     C1      C2      C3     DAYS    DAYS    DEP     DAYS    DAYS    SEA     TBLD     DEP

  1  CV    43  CORAL SEA            0.0    0.0     0.0     0.0     0.0       0       0    0.00       0       0    0.00       0     3365
  2  CV    59  FORRESTAL            0.0    0.0     0.0     0.0     0.0       0       0    0.00       0       0    0.00       0     3365
  3  CV    60  SARATOGA            14.3   14.3     0.0     9.2     5.1     275       0    0.00     275      66    0.24       0     3030
  4  CV    62  INDEPENDENCE       132.5  132.5    47.0    81.4     4.1    1290     511    0.40     779     239    0.31     313     3365
  5  CV    66  AMERICA            173.5  173.5     0.0   169.6     3.9     842     450    0.53     392     111    0.28       0     3153
  6  CV    67  KENNEDY            186.9  186.9     0.0   185.4     1.4    1296     617    0.48     679     219    0.32       0     3140
  7  CVN   68  NIMITZ              12.5   12.5     0.0     5.4     7.1    1262     366    0.29     896     263    0.29       0     2043
  8  CVN   69  EISENHOWER         165.4  165.4    65.0    99.2     1.2    1459     585    0.40     874     285    0.33     295     3325
  9  CVN   70  VINSON C           225.9  226.4   127.5    94.4     4.5     296     193    0.65     103      12    0.12     105     3255
 10  CG    17  YARNELL HE           7.8    7.8     6.0     0.4     1.4    1304     430    0.33     910     296    0.33     420     3365
 11  CG    19  DALE                32.5   32.5     0.0    32.5     0.0     509     202    0.40     307     102    0.33       0     3153
 12  CG    20  TURNER RK           44.9   45.4    40.5     4.6     0.4     350      71    0.20     279      91    0.33     279     3365
 13  CG    26  BELKNAP             39.5   40.2     2.7    28.0     9.5     949     344    0.36     605     154    0.25     387     3325
 14  CG    27  DANIELS J            5.6    5.6     0.0     3.0     2.6      90       0    0.00      90      17    0.19       0     3275
 15  CG    28  WAINWRIGHT          13.2   13.2     0.0    12.1     1.0     364       0    0.00     364     116    0.32       0     3365
 16  CG    34  BIDDLE              87.0   87.0    48.0    38.7     0.4    1049     388    0.37     660     218    0.33     312     3365
 17  CGN   36  CALIFORNIA           8.0    8.0     0.0     7.6     0.4     227       0    0.00     227      76    0.33       0     3138
 18  CGN   37  SOUTH CAROLINA       0.0    0.0     0.0     0.0     0.0       0       0    0.00       0       0    0.00       0     3365
 19  CGN   38  VIRGINIA           122.4  122.4    65.0    53.2     4.3    1459     539    0.37     920     285    0.31     295     3325
 20  CGN   39  TEXAS              137.6  138.0     2.4   129.4     6.1    1350     579    0.43     771     226    0.29     384     3255
 21  CGN   40  MISSISSIPPI         54.3   54.3     0.0    48.1     6.3    1177     440    0.37     737     214    0.29       0     3140
 22  CGN   41  ARKANSAS            36.3   36.3     0.0    34.8     1.4     463     189    0.41     274      84    0.31       0     3140
 23  CG    47  TICONDEROGA         52.1   52.6    48.5     4.0     0.1     334      71    0.21     263      87    0.33     263     3365
 24  DDG    2  ADAMS CF             1.9    1.9     0.0     1.0     0.9      31       0    0.00      31       6    0.19       0     3365
 25  DDG    3  KING J              13.6   13.6     0.0     9.3     4.3     278       0    0.00     278      71    0.26       0     3087
 26  DDG    4  LAWRENCE            79.6   80.1    39.5    28.2    12.4     522     202    0.39     320     119    0.37     281     3325
 27  DDG    5  RICKETTS CV        101.1  101.1    59.0    40.8     1.2     454     192    0.42     262      81    0.31     242     3344
 28  DDG    6  BARNEY              31.4   31.4     0.0    25.4     6.0    1101     392    0.36     709     206    0.29       0     2194
 29  DDG   10  SAMPSON             12.4   12.4     0.0     5.5     6.9     551     189    0.34     362      86    0.24       0     3140
 30  DDG   11  SELLERS              8.5    8.5     0.0     4.6     3.9     139       0    0.00     139      27    0.19       0     3226
 31  DDG   17  CONYNGHAM           27.9   28.7     1.8    21.0     5.9    1024     362    0.35     680     197    0.29     378     3255
 32  DDG   18  SEMMES              55.2   55.7    51.5     3.8     0.4     328      71    0.22     257      86    0.33     257     3365
 33  DDG   19  TATTNALL           142.0  142.5    79.5    62.8     0.3     394     194    0.49     220      72    0.33     201     3365
 34  DDG   23  BYRD RE             13.6   11.2     0.0     8.9     2.2     641     124    0.19     517     161    0.31       0     3075
 35  DDG   37  FARRAGUT            61.4   61.4     0.0    60.1     1.3    1267     482    0.38     785     255    0.32       0     3140
 36  DDG   38  LUCE                11.7   11.7     0.0     9.6     2.1     287       0    0.00     287      85    0.30       0     3078
 37  DDG   39  MCDONOUGH           54.5   54.5    52.0     2.1     0.4    1229     388    0.32     841     278    0.33     308     3365
 38  DDG   40  COONTZ              10.7   10.7     0.0     5.8     4.9     175       0    0.00     175      34    0.19       0     3190
 39  DDG   41  KING                13.1   13.1     0.0     7.2     5.9     215       0    0.00     215      42    0.20       0     3150
 40  DDG   42  MAHAN               35.5   35.5    23.0    10.3     2.2     889     193    0.22     696     234    0.34     590     3255
 41  DDG   43  DAHLGREN            65.1   65.1     0.0    61.2     3.9    1459     547    0.37     912     284    0.31       0     3153
 42  DDG   44  PRATT WV             8.4    6.6     0.0     6.1     0.5    1279     365    0.29     914     302    0.33       0     2347
 43  DDG   45  DEWEY               52.3   46.5    39.0     1.7     5.8     919     289    0.31     630     181    0.29     321     3273
 44  DDG   46  PREBLE              10.8   10.8     0.0     9.9     0.8     298       0    0.00     298      95    0.32       0     3067
 45  DDG  993  KIDD                69.9   69.9    39.0    29.2     1.7     519     202    0.39     317      97    0.31     282     3325
 46  DDG  995  SCOTT               61.4   61.9    59.5     1.8     0.7     335      94    0.28     241      77    0.32     241     3365
 47  DD   944  MULLINNIX           22.3   22.3     0.0     2.2    20.1     484     139    0.29     345     135    0.39       0     3140
 48  DD   963  SPRUANCE           176.2  176.2     0.0   175.6     0.6     728     418    0.57     310     100    0.32       0     3254
 49  DD   968  RADFORD AW          55.0   55.0    24.0    17.9    13.1     553     202    0.37     351     130    0.37     312     3325
 50  DD   969  PETERSON             9.1    9.1     0.0     8.7     0.4     260       0    0.00     260      87    0.33       0     3105
```

NR.	HULL NR.		SHIP NAME	SKED COST	SHIP COST	C1	C2	C3	CY DAYS	DEP DAYS	PCT DEP	HOME DAYS	SEA DAYS	PCT SEA	TILD	LAST DEP
51	DD	970	CARON	74.3	65.5	63.5	1.5	0.5	327	94	0.29	233	75	0.32	233	3365
52	DD	974	COMTE DE GRASSE	173.3	173.3	0.0	168.8	4.5	1382	629	0.46	753	228	0.30	0	3211
53	DD	977	BRISCOE	7.6	7.6	0.0	5.8	1.8	174	0	0.00	174	49	0.28	0	3191
54	DD	978	STUMP	37.9	37.9	0.0	35.8	2.1	1286	464	0.36	822	263	0.32	0	3075
55	DD	979	CONOLLY	62.6	63.5	7.9	51.8	3.8	1424	526	0.37	898	280	0.31	439	3325
56	DD	980	MOOSBRUGGER	8.2	8.2	0.0	8.1	0.1	244	0	0.00	244	81	0.33	0	3121
57	DD	981	HANCOCK J	5.3	5.3	0.0	2.8	2.5	85	0	0.00	85	16	0.19	0	3280
58	DD	982	NICHOLSON	9.9	9.9	0.0	9.2	0.7	275	0	0.00	275	88	0.32	0	3090
59	DD	983	RODGERS J	7.8	7.8	0.0	7.7	0.1	230	0	0.00	230	76	0.33	0	3135
60	DD	987	OBANNON	10.3	10.3	0.0	9.7	0.6	291	0	0.00	291	94	0.32	0	3074
61	DD	988	THORN	7.9	7.9	0.0	7.8	0.1	235	0	0.00	235	78	0.33	0	3130
62	DD	997	HAYLOR	5.2	5.2	0.0	2.8	2.4	84	0	0.00	84	16	0.19	0	3281
63	DD	989	DEYO	117.2	117.2	110.0	4.2	3.0	1014	296	0.29	718	224	0.31	250	3355
64	FFG	4	TALBOT	8.8	8.8	0.0	6.7	2.1	200	0	0.00	200	56	0.28	0	3365
65	FFG	5	PAGE RL	0.0	0.0	0.0	0.0	0.0	0	0	0.00	0	0	0.00	0	3365
66	FFG	6	FURER JA	11.1	11.1	0.0	9.7	1.4	832	180	0.22	652	210	0.32	0	2348
67	FFG	7	PERRY OH	159.7	159.7	0.0	153.7	6.0	1094	518	0.47	576	162	0.28	0	3254
68	FFG	8	MCINERNEY	2.9	2.9	0.0	2.0	0.9	629	189	0.30	440	142	0.32	0	3140
69	FFG	11	CLARK	15.6	15.3	9.6	4.2	1.5	729	247	0.34	482	153	0.32	456	3365
70	FFG	13	MORISON SE	12.7	12.0	9.0	2.2	0.8	729	221	0.30	508	164	0.32	351	3365
71	FFG	15	ESTOCIN	4.9	4.9	0.0	4.4	0.5	674	180	0.27	494	165	0.33	0	2348
72	FFG	16	SPRAGUE C	2.0	2.0	0.0	0.7	1.2	589	189	0.32	400	127	0.32	0	3140
73	FFG	20	ANTRIM	15.5	14.7	8.0	6.7	0.0	414	71	0.17	343	114	0.33	344	3365
74	FFG	21	FLATLEY	14.7	14.7	8.0	6.7	0.0	414	71	0.17	343	114	0.33	344	3365
75	FFG	22	FAHRION	10.6	10.6	0.0	9.9	0.7	296	0	0.00	296	95	0.32	0	3069
76	FFG	24	WILLIAMS J	14.9	14.9	8.0	6.7	0.2	414	71	0.17	343	113	0.33	344	3365
77	FFG	26	GALLERY	28.7	28.7	23.0	5.7	0.0	384	71	0.18	313	104	0.33	314	3365
78	FFG	28	BOONE	6.9	6.9	0.0	5.6	1.3	169	0	0.00	169	50	0.30	0	3196
79	FFG	29	GROVES SW	4.5	4.5	0.0	4.1	0.4	123	0	0.00	123	39	0.32	0	3242
80	FFG	31	STARK	0.0	0.0	0.0	0.0	0.0	0	0	0.00	0	0	0.00	0	3365
81	FFG	32	HALL JL	5.4	5.4	0.0	4.6	0.8	138	0	0.00	138	42	0.30	0	3227
82	FFG	34	FITCH A	2.5	2.5	0.0	1.4	1.1	41	0	0.00	41	8	0.20	0	3324
83	FF	1038	MCCLOY	8.5	7.7	6.5	0.7	0.5	1264	414	0.33	840	277	0.33	425	3365
84	FF	1040	GARCIA	75.4	75.9	54.5	19.5	1.9	419	159	0.38	260	77	0.30	251	3355
85	FF	1043	MCDONNELL E	4.1	4.1	0.0	3.9	0.2	556	189	0.34	367	121	0.33	0	3140
86	FF	1044	BRUMBY	8.6	8.6	0.0	8.6	0.0	714	152	0.21	562	187	0.33	0	3153
87	FF	1047	VOGE	6.8	6.8	0.0	3.7	3.1	110	0	0.00	110	21	0.19	0	3255
88	FF	1049	KOELSCH	6.3	6.3	0.0	3.4	2.9	103	0	0.00	103	20	0.19	0	3262
89	FF	1056	CONNOLE	7.5	7.5	0.0	3.8	3.7	1455	444	0.31	1011	318	0.31	0	3142
90	FF	1059	SIMS WS	26.9	24.1	14.0	10.0	0.1	1299	333	0.26	966	322	0.33	346	3365
91	FF	1061	PATTERSON	7.8	7.8	0.0	7.7	0.1	230	0	0.00	230	76	0.33	0	3135
92	FF	1068	VREELAND	30.8	20.0	14.8	4.4	0.8	739	202	0.27	537	135	0.25	508	3325
93	FF	1072	BLAKELY	7.3	6.9	0.0	1.4	5.6	1063	340	0.32	723	213	0.29	0	2365
94	FF	1075	TRIPPE	57.7	58.6	7.9	48.3	2.4	969	371	0.38	598	187	0.31	439	3325
95	FF	1078	HEWES J	16.7	11.8	3.1	0.8	7.8	632	202	0.32	430	151	0.35	391	3325
96	FF	1079	BOWEN	52.6	52.6	38.0	6.3	8.3	849	289	0.34	560	145	0.26	322	3273
97	FF	1080	PAUL	56.2	56.7	54.5	2.1	0.1	345	94	0.27	251	83	0.33	251	3365
98	FF	1081	AYLWIN	50.5	50.5	46.0	3.7	0.8	864	251	0.29	613	200	0.33	314	3365
99	FF	1082	MONTGOMERY E	7.0	7.0	0.0	1.9	3.1	116	0	0.00	116	23	0.20	0	3249
100	FF	1084	MCCANDLESS	0.0	0.0	0.0	0.0	0.0	0	0	0.00	0	0	0.00	0	3365
101	FF	1085	BEARY DB	39.1	39.9	1.8	36.2	2.0	1459	522	0.36	937	314	0.34	378	3255
102	FF	1089	BROWN JL	64.5	64.5	61.0	1.6	1.9	1459	470	0.32	989	320	0.32	299	3344
103	FF	1090	AINSWORTH	11.6	11.6	0.0	2.1	9.5	1272	436	0.32	936	264	0.28	0	3140
104	FF	1091	MILLER	45.2	45.9	29.7	11.2	5.1	1459	497	0.34	962	295	0.31	657	3325
105	FF	1092	HART TC	68.6	63.2	61.0	0.2	2.0	1459	488	0.33	971	314	0.32	299	3344
106	FF	1093	CAPODANNO	42.3	42.3	0.0	34.1	8.2	1321	474	0.36	847	241	0.28	0	3140

```
NR.   HULL      SHIP NAME          SKED  SHIP                                 CY     DEP    PCT    HOME   SEA    PCT           LAST
      NR.                          COST  COST    C1      C2      C3          DAYS   DAYS   DEP    DAYS   DAYS   SEA    TBLD    DEP

107  FF 1094 PHARRIS               81.0  81.6   23.6    57.2     0.9   1459    543  0.37    896    294   0.33    596    3255
108  FF 1095 TRUETT                 4.4   3.5    0.0     0.7     2.8   1381    453  0.33    928    295   0.32      0    2345
109  FF 1096 VALDEZ                59.6  60.4    2.8    50.2     7.5   1459    536  0.37    923    270   0.29    388    3325
110  FF 1097 MOINESTER             50.5  36.3    7.9    24.3     4.0   1041    371  0.36    670    203   0.30    439    3325
111  FF 1098 GLOVER                20.1  20.1    0.0    18.0     2.2    904    319  0.35    585    184   0.31      0    3140

                   AVERAGES        43.15  42.68  34.66  24.57    2.93 705.98 314.51   0.34 481.70 149.19   0.30 344.43

         STANDARD DEVIATIONS       48.91  49.00  28.92  40.11    3.28 468.49 162.06   0.09 285.21 259.14   0.05 103.21

              NON ZEROS (N)       105.00 105.00  46.00 105.00 105.00 105.00  75.00  75.00 105.00 105.00 105.00  46.00
```

APPENDIX D

SAMPLE EVENT REPORT

The Event Report lists all primary events that have been scheduled. The "Type Requirement" line indicates the constraint row numbers associated with the event/ship-type requirements in CPSKED and the number of units of each type required. The ships assigned by CPSKED are listed under "Forces Assigned."

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                         EVENT REPORT
EVENT FILE:   EVENTLG (CPSKED)          SHIP FILE:  LANTFLT COMBATANTS


MED 1-83                    START DATE: 3001   STOP DATE: 3171

TYPE REQMTS( 112- 117): CV/CVN: 1   CG/CGN: 2  DDG: 2  DD: 1  FFG: 2  FF: 5

FORCES ASSIGED:
      67  KENNEDY
      40  MISSISSIPPI
      41  ARKANSAS
      10  SAMPSON
      37  FARRAGUT
     944  MULLINNIX
       8  MC INERNEY
      16  SPRAGUE C
    1043  MC DONNELL E
    1056  CONNOLE
    1090  AINSWORTH
    1093  CAPODANNO
    1098  GLOVER

IO 1-83                     START DATE: 3001   STOP DATE: 3183

TYPE REQMTS( 118- 121): CV/CVN: 1   CG/CGN: 1  DDG: 1  DD: 0  FFG: 0  FF: 1

FORCES ASSIGED:
      66  AMERICA
      19  DALE
      43  DAHLGREN
    1044  BRUMBY

MEF 1-83                    START DATE: 3001   STOP DATE: 3105

TYPE REQMTS( 122- 123): CV/CVN: 0   CG/CGN: 0  DDG: 1  DD: 1  FFG: 0  FF: 0

FORCES ASSIGED:
      23  BYRD RE
     978  STUMP

MEF 2-83                    START DATE: 3001   STOP DATE: 3213

TYPE REQMTS( 124- 125): CV/CVN: 0   CG/CGN: 0  DDG: 0  DD: 1  FFG: 1  FF: 0

FORCES ASSIGED:
     963  SPRUANCE
       7  PERRY OH

SNFL 1-83                   START DATE: 3001   STOP DATE: 3242

TYPE REQMTS( 126- 126): CV/CVN: 0   CG/CGN: 0  DDG: 0  DD: 1  FFG: 0  FF: 0

FORCES ASSIGED:
     974  COMTE DE GRASSE

IO 2-83                     START DATE: 3031   STOP DATE: 3285

TYPE REQMTS( 127- 130): CV/CVN: 1   CG/CGN: 1  DDG: 1  DD: 0  FFG: 0  FF: 1

FORCES ASSIGED:
      70  VINSON C
     39   TEXAS
     17   CONYNGHAM
     42   MAHAN
   1085   BEARY DB
   1094   PHARRIS

MED 2-83              START DATE: 3069   STOP DATE: 3355

TYPE REQMTS( 131- 136): CV/CVN: 1   CG/CGN: 2   DDG: 2   DD: 2   FFG: 3   FF: 3

FORCES ASSIGED:
     69   EISENHOWER
     26   BELKNAP
     38   VIRGINIA
      4   LAWRENCE
    993   KIDD
    968   RADFORD AW
    979   CONOLLY
   1068   VREELAND
   1075   TRIPPE
   1078   HEWES J
   1091   MILLER
   1096   VALDEZ
   1097   MOINESTER

COMPTUEX 2-83         START DATE: 3095   STOP DATE: 3112

TYPE REQMTS( 137- 141): CV/CVN: 0   CG/CGN: 2   DDG: 2   DD: 2   FFG: 3   FF: 3

FORCES ASSIGED:
     17   YARNELL HE
     20   TURNER RK
     28   WAINWRIGHT
      5   RICKETTS CV
     19   TATTNALL
    995   SCOTT
    970   CARON
    982   NICHOLSON
    989   DEYO
      6   FURER JA
     15   ESTOCIN
     20   ANTRIM
     21   FLATLEY
     26   GALLERY
   1040   GARCIA
   1072   BLAKELY
   1080   PAUL
   1089   BROWN JL
   1092   HART TC

MEF 3-83              START DATE: 3107   STOP DATE: 3303

TYPE REQMTS( 142- 143): CV/CVN: 0   CG/CGN: 0   DDG: 0   DD: 1   FFG: 0   FF: 1

FORCES ASSIGED:
     45   DEWEY
   1079   BOWEN

SOLID SHIELD 83       START DATE: 3119   STOP DATE: 3131

TYPE REQMTS( 144- 149): CV/CVN: 1   CG/CGN: 2   DDG: 2   DD: 2   FFG: 2   FF: 2

FORCES ASSIGED:
     60   SARATOGA
    68  NIMITZ
    17  YARNELL HE
    28  WAINWRIGHT
    19  TATTNALL
    38  LUCE
    44  PRATT WV
   995  SCOTT
   970  CARON
   978  STUMP
   989  DEYO
  1038  MCCLOY
  1059  SIMS WS
  1072  BLAKELY
  1081  AYLWIN
  1092  HART TC
  1095  TRUETT

SNFL 2-83              START DATE: 3140  STOP DATE: 3365

TYPE REQMTS( 150- 150): CV/CVN: 0  CG/CGN: 0  DDG: 1  DD: 0  FFG: 0  FF: 0

FORCES ASSIGED:
    19  TATTNALL

OCEAN SAFARI 83        START DATE: 3148  STOP DATE: 3198

TYPE REQMTS( 151- 155): CV/CVN: 1  CG/CGN: 2  DDG: 1  DD: 2  FFG: 2  FF: 0

FORCES ASSIGED:
    67  KENNEDY
    34  BIDDLE
    23  BYRD RE
    39  MCDONOUGH
    44  PRATT WV
    46  PREBLE
   969  PETERSON
   987  OBANNON
     6  FURER JA
    11  CLARK
    22  FARION
  1095  TRUETT

COMPTUEX 3-83          START DATE: 3152  STOP DATE: 3168

TYPE REQMTS( 156- 160): CV/CVN: 0  CG/CGN: 2  DDG: 2  DD: 2  FFG: 3  FF: 3

FORCES ASSIGED:
    17  YARNELL HE
    36  CALIFORNIA
    47  TICONDEROGA
     3  KING J
    18  SEMMES
    38  LUCE
   978  STUMP
   980  MOOSBRUGGER
   983  RODGERS J
    13  MORISON SE
    15  ESTOCIN
    24  WILLIAMS J
    1038  MCCLOY
    1059  SIMS WS
    1061  PATTERSON
    1080  PAUL
    1081  AYLWIN

UNITAS                  START DATE: 3152  STOP DATE: 3365

TYPE REQMTS( 161- 163): CV/CVN: 0  CG/CGN: 0  DDG: 1  DD: 1  FFG: 0  FF: 1

FORCES ASSIGED:
       5  RICKETTS CV
    1089  BROWN JL
    1092  HART TC

MEF 4-83                START DATE: 3166  STOP DATE: 3365

TYPE REQMTS( 164- 165): CV/CVN: 0  CG/CGN: 0  DDG: 0  DD: 1  FFG: 0  FF: 1

FORCES ASSIGED:
     989  DEYO
    1040  GARCIA

COMPTUEX 4-83           START DATE: 3221  STOP DATE: 3238

TYPE REQMTS( 166- 170): CV/CVN: 0  CG/CGN: 2  DDG: 2  DD: 2  FFG: 3  FF: 3

FORCES ASSIGED:
      17  YARNELL HE
      19  DALE
      41  ARKANSAS
      37  FARRAGUT
      43  DAHLGREN
      44  PRATT WV
     980  MOOSBRUGGER
     982  NICHOLSON
     988  THORN
       4  TALBOT
       8  MCINERNEY
      15  ESTOCIN
      16  SPRAGUE C
      28  BOONE
    1043  MCDONNELL E
    1056  CONNOLE
    1059  SIMS WS
    1090  AINSWORTH
    1098  GLOVER

IO 1-84                 START DATE: 3241  STOP DATE: 3365

TYPE REQMTS( 171- 173): CV/CVN: 0  CG/CGN: 1  DDG: 1  DD: 0  FFG: 0  FF: 1

FORCES ASSIGED:
      17  YARNELL HE
     995  SCOTT
     970  CARON
      11  CLARK
    1080  PAUL

MED 1-84                START DATE: 3244  STOP DATE: 3365

TYPE REQMTS( 174- 179): CV/CVN: 1  CG/CGN: 2  DDG: 2  DD: 2  FFG: 3  FF: 3

FORCES ASSIGED:
      62  INDEPENDENCE
      20  TURNER RK
      34  BIDDLE
      47  TICONDEROGA
      18  SEMMES
      39  MCDONOUGH
      13  MORISON SE
      20  ANTRIM
      21  FLATLEY
      24  WILLIAMS J
      26  GALLERY
    1038  MCCLOY
    1059  SIMS WS
    1081  AYLWIN

COMPTUEX 1-84         START DATE: 3334  STOP DATE: 3349

TYPE REQMTS( 180- 184): CV/CVN: 0  CG/CGN: 2  DDG: 2  DD: 2  FFG: 3  FF: 3

FORCES ASSIGED:
      19  DALE
      28  WAINWRIGHT
      36  CALIFORNIA
      17  CONYNGHAM
      43  DAHLGREN
      45  DEWEY
     977  BRISCOE
     983  RODGERS J
     988  THORN
       8  MCINERNEY
      15  ESTOCIN
      16  SPRAGUE C
      29  GROVES SW
      32  HALL JL
    1043  MCDONNELL E
    1056  CONNOLE
    1061  PATTERSON
    1079  BOWEN
    1098  GLOVER
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APPENDIX E

SAMPLE SHIP SCHEDULE REPORT

The Ship Schedule Report is in a format similar to the CINCLANTFLT Quarterly Employment Schedule. All EMPTERMS associated with a primary event are listed.

```
         SHIP SCHEDULE REPORT
EVENT FILE:  EVENTLG (CPSKED)        SHIP FILE:  LANTFLT COMBATANTS

UNIT IDENTIFICATION                          START     END  EMPLOYMENT    LOCATION          EMP UNIT/EXERCISE NO.

CV    43  CORAL SEA          N00000
CV    59  FORRESTAL          N03359
CV    60  SARATOGA           N03360
                                               3119     3131  E   EXER         ATLANTIC OCEAN
                                                  * * R E M A R K - SOLID SHIELD 83
CV    62  INDEPENDENCE       N03362
                                               3244     3263  E   READEX                         02-83
                                               3264     3293  E   POM
                                               3294     3303  E   ENR          ROTA
                                               3294     3365  C   DEPLOY
                                                  * * R E M A R K - MED 1-84
                                               3304     3365  E   OPCON                          CINCUSNAVEUR
CV    66  AMERICA            N03366
                                               3001     3143  E   OPCON                          CINCPACFLT
                                               3001     3153  C   DEPLOY
                                                  * * R E M A R K - ID 1-83
                                               3144     3153  E   ENR          CONUS
                                               3154     3183  E   LVUPK
CV    67  KENNEDY            N03367
                                               3001     3130  E   OPCON                          CINCUSNAVEUR
                                               3001     3140  C   DEPLOY
                                                  * * R E M A R K - MED 1-83
                                               3131     3140  E   ENR          CONUS
                                               3141     3170  E   LVUPK
                                               3148     3157  E   EXER         ATLANTIC OCEAN
                                                  * * R E M A R K - UNITED EFFORT
                                               3158     3168  E   EXER         NORTH ATLANTIC
                                                  * * R E M A R K - OCEAN SAFARI 83
                                               3180     3188  E   EXER         NORTH ATLANTIC
                                                  * * R E M A R K - BALTOPS 83
                                               3189     3198  E   ENR          CONUS
CVN   68  NIMITZ             N03368
                                               3119     3131  E   EXER         ATLANTIC OCEAN
                                                  * * R E M A R K - SOLID SHIELD 83
CVN   69  EISENHOWER         N03369
                                               3069     3092  E   READEX       CARIBBEAN SEA     01-83
                                               3093     3122  E   POM
                                               3123     3133  E   ENR          ROTA
                                               3123     3325  C   DEPLOY
                                                  * * R E M A R K - MED 2-83
                                               3133     3315  E   OPCON                          CINCUSNAVEUR
                                               3316     3325  E   ENR          CONUS
                                               3326     3355  E   LVUPK
CVN   70  VINSON C           N20993
                                               3031     3061  E   POM
                                               3062     3071  E   ENR          ROTA
                                               3062     3255  C   DEPLOY
                                                  * * R E M A R K - ID 2-83
                                               3071     3246  E   OPCON                          CINCPACFLT
                                               3246     3255  E   ENR          CONUS
                                               3256     3285  E   LVUPK
CG    17  YARNELL HE         N52688
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UNIT IDENTIFICATION                          START    END   EMPLOYMENT    LOCATION        EMP UNIT/EXERCISE NO.

                                              3095    3112  E   COMPTUEX                          02-83
                                              3119    3131  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - SOLID SHIELD 83
                                              3152    3168  E   COMPTUEX                          03-83
                                              3221    3238  E   COMPTUEX                          04-83
                                              3241    3270  E   POM
                                              3271    3281  E   ENR        ROTA
                                              3271    3365  C   DEPLOY
                                                 * * R E M A R K - IO 1-84
                                              3282    3365  E   OPCON                             CINCPACFLT
CG    19  DALE                N52690
                                              3001    3143  E   OPCON                             CINCPACFLT
                                              3001    3153  C   DEPLOY
                                                 * * R E M A R K - IC 1-83
                                              3144    3153  E   ENR        CONUS
                                              3154    3183  E   LVUPK
                                              3221    3238  E   COMPTUEX                          04-83
                                              3334    3349  E   COMPTUEX                          01-84
CG    20  TURNER RK           N52691
                                              3095    3112  E   COMPTUEX                          02-83
                                              3244    3263  E   READEX                            02-83
                                              3264    3293  E   POM
                                              3294    3303  E   ENR        ROTA
                                              3294    3365  C   DEPLOY
                                                 * * R E M A R K - MED 1-84
                                              3304    3365  E   OPCON                             CINCUSNAVEUR
CG    26  BELKNAP             N52701
                                              3069    3092  E   READEX     CARIBBEAN SEA          01-83
                                              3093    3122  E   POM
                                              3123    3133  E   ENR        ROTA
                                              3123    3325  C   DEPLOY
                                                 * * R E M A R K - MED 2-83
                                              3133    3315  E   OPCON                             CINCUSNAVEUR
                                              3316    3325  E   ENR        CONUS
                                              3326    3355  E   LVUPK
CG    27  DANIELS J           N52702
CG    28  WAINWRIGHT          N52703
                                              3095    3112  E   COMPTUEX                          02-83
                                              3119    3131  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - SOLID SHIELD 83
                                              3334    3349  E   COMPTUEX                          01-84
CG    34  BIDDLE              N52709
                                              3148    3157  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - UNITED EFFORT
                                              3158    3168  E   EXER       NORTH ATLANTIC
                                                 * * R E M A R K - OCEAN SAFARI 83
                                              3180    3188  E   EXER       NORTH ATLANTIC
                                                 * * R E M A R K - BALTOPS 83
                                              3189    3198  E   ENR        CONUS
                                              3244    3263  E   READEX                            02-83
                                              3264    3293  E   POM
                                              3294    3303  E   ENR        ROTA
                                              3294    3365  C   DEPLOY
                                                 * * R E M A R K - MED 1-84
                                              3304    3365  E   OPCON                             CINCUSNAVEUR
CGN   36  CALIFORNIA          N20541
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UNIT IDENTIFICATION                              START     END   EMPLOYMENT     LOCATION          EMP UNIT/EXERCISE NO.

                                                  3152     3168  E   COMPTUEX                          03-83
                                                  3334     3349  E   COMPTUEX                          01-84
CGN   37  SOUTH CAROLINA       N20669
CGN   38  VIRGINIA             N20681
                                                  3069     3092  E   READEX      CARIBBEAN SEA         01-83
                                                  3093     3122  E   POM
                                                  3123     3133  E   ENR         ROTA
                                                  3123     3325  C   DEPLOY
                                                     * * R E M A R K - MED 2-83
                                                  3133     3315  E   OPCON                             CINCUSNAVEUR
                                                  3316     3325  E   ENR         CONUS
                                                  3326     3355  E   LVUPK
CGN   39  TEXAS                N20682
                                                  3031     3061  E   POM
                                                  3062     3071  E   ENR         ROTA
                                                  3062     3255  C   DEPLOY
                                                     * * R E M A R K - IO 2-83
                                                  3071     3246  E   OPCON                             CINCPACFLT
                                                  3246     3255  E   ENR         CONUS
                                                  3256     3285  E   LVUPK
CGN   40  MISSISSIPPI          N20624
                                                  3001     3130  E   OPCON                             CINCUSNAVEUR
                                                  3001     3140  C   DEPLOY
                                                     * * R E M A R K - MED 1-83
                                                  3131     3140  E   ENR         CONUS
                                                  3141     3170  E   LVUPK
CGN   41  ARKANSAS             N20807
                                                  3001     3130  E   OPCON                             CINCUSNAVEUR
                                                  3001     3140  C   DEPLOY
                                                     * * R E M A R K - MED 1-83
                                                  3131     3140  E   ENR         CONUS
                                                  3141     3170  E   LVUPK
                                                  3221     3238  E   COMPTUEX                          04-83
CG    47  TICONDEROGA          N00000
                                                  3152     3168  E   COMPTUEX                          03-83
                                                  3244     3263  E   READEX                            02-83
                                                  3264     3293  E   POM
                                                  3294     3303  E   ENR         ROTA
                                                  3294     3365  C   DEPLOY
                                                     * * R E M A R K - MED 1-84
                                                  3304     3365  E   OPCON                             CINCUSNAVEUR
DDG    2  ADAMS CF             N04668
DDG    3  KING J               N04669
                                                  3152     3168  E   COMPTUEX                          03-83
DDG    4  LAWRENCE             N04670
                                                  3069     3092  E   READEX      CARIBBEAN SEA         01-83
                                                  3093     3122  E   POM
                                                  3123     3133  E   ENR         ROTA
                                                  3123     3325  C   DEPLOY
                                                     * * R E M A R K - MED 2-83
                                                  3133     3315  E   OPCON                             CINCUSNAVEUR
                                                  3316     3325  E   ENR         CONUS
                                                  3326     3355  E   LVUPK
DDG    5  RICKETTS CV          N04671
                                                  3095     3112  E   COMPTUEX                          02-83
                                                  3121     3151  E   POM
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UNIT IDENTIFICATION                              START      END   EMPLOYMENT     LOCATION          EMP UNIT/EXERCISE NO.

                                                   3152     3344  E   OPCON                           COMSOLANT
                                                   3152     3344  C   DEPLOY
                                                      * * R E M A R K - UNITAS - WATC
                                                   3345     3365  E   LVUPK
DDG     6  BARNEY                    N04672
DCG    10  SAMPSON                   N04676
                                                   3001     3130  E   OPCON                           CINCUSNAVEUR
                                                   3001     3140  C   DEPLOY
                                                      * * R E M A R K - MED 1-83
                                                   3131     3140  E   ENR          CONUS
                                                   3141     3170  E   LVUPK
DDG    11  SELLERS                   N04677
DDG    17  CONYNGHAM                 N04683
                                                   3031     3061  E   POM
                                                   3062     3071  E   ENR          ROTA
                                                   3062     3255  C   DEPLOY
                                                      * * R E M A R K - ID 2-83
                                                   3071     3246  E   OPCON                           CINCPACFLT
                                                   3246     3255  E   ENR          CONUS
                                                   3256     3285  E   LVUPK
                                                   3334     3349  E   COMPTUEX                        01-84
DDG    18  SEMMES                    N04684
                                                   3152     3168  E   COMPTUEX                        03-83
                                                   3244     3263  E   READEX                          02-83
                                                   3264     3293  E   POM
                                                   3294     3303  E   ENR          ROTA
                                                   3294     3365  C   DEPLOY
                                                      * * R E M A R K - MED 1-84
                                                   3304     3365  E   OPCON                           CINCUSNAVEUR
DDG    19  TATTNALL                  N04685
                                                   3095     3112  E   COMPTUEX                        02-83
                                                   3119     3131  E   EXER         ATLANTIC OCEAN
                                                      * * R E M A R K - SOLID SHIELD 83
                                                   3140     3170  E   POM
                                                   3171     3180  E   ENR
                                                   3171     3365  C   DEPLOY
                                                      * * R E M A R K - SNFL 2-83
                                                   3161     3355  E   OPCON                           STANAVFORLANT
                                                   3355     3365  E   ENR          CONUS
DCG    23  BYRD RE                   N04690
                                                   3001     3064  E   OPCON                           COMIDEASTFOR
                                                   3001     3075  C   DEPLOY
                                                      * * R E M A R K - MEF 1-83
                                                   3065     3075  E   ENR          CONUS
                                                   3076     3105  E   LVUPK
                                                   3148     3157  E   EXER         ATLANTIC OCEAN
                                                      * * R E M A R K - UNITED EFFORT
                                                   3158     3168  E   EXER         NORTH ATLANTIC
                                                      * * R E M A R K - OCEAN SAFARI 83
                                                   3180     3188  E   EXER         NORTH ATLANTIC
                                                      * * R E M A R K - BALTOPS 83
                                                   3189     3198  E   ENR          CONUS
DDG    37  FARRAGUT                  N52231
                                                   3001     3130  E   OPCON                           CINCUSNAVEUR
                                                   3001     3140  C   DEPLOY
                                                      * * R E M A R K - MED 1-83
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UNIT IDENTIFICATION                    START     END   EMPLOYMENT    LOCATION         EMP UNIT/EXERCISE NO.

                                        3131     3140  E   ENR       CONUS
                                        3141     3170  E   LVUPK
                                        3221     3238  E   COMPTUEX                     04-83
DDG   38  LUCE            N52232
                                        3119     3131  E   EXER      ATLANTIC OCEAN
                                           * * R E M A R K - SOLID SHIELD 83
                                        3152     3168  E   COMPTUEX                     03-83
DDG   39  MCDONOUGH       N52233
                                        3148     3157  E   EXER      ATLANTIC OCEAN
                                           * * R E M A R K - UNITED EFFORT
                                        3158     3168  E   EXER      NORTH ATLANTIC
                                           * * R E M A R K - OCEAN SAFARI 83
                                        3180     3188  E   EXER      NORTH ATLANTIC
                                           * * R E M A R K - BALTOPS 83
                                        3189     3198  E   ENR       CONUS
                                        3244     3263  E   READEX                       02-83
                                        3264     3293  E   POM
                                        3294     3303  E   ENR       ROTA
                                        3294     3365  C   DEPLDY
                                           * * R E M A R K - MED 1-84
                                        3304     3365  E   DPCON                        CINCUSNAVEUR
DDG   40  COONTZ          N52234
DDG   41  KING            N52235
DDG   42  MAHAN           N52236
                                        3031     3061  E   POM
                                        3062     3071  E   ENR       ROTA
                                        3062     3255  C   DEPLDY
                                           * * R E M A R K - IO 2-83
                                        3071     3246  E   DPCON                        CINCPACFLT
                                        3246     3255  E   ENR       CONUS
                                        3256     3285  E   LVUPK
DDG   43  DAHLGREN        N52683
                                        3001     3143  E   OPCON                        CINCPACFLT
                                        3001     3153  C   DEPLDY
                                           * * R E M A R K - IO 1-83
                                        3144     3153  E   ENR       CONUS
                                        3154     3183  E   LVUPK
                                        3221     3238  E   COMPTUEX                     04-83
                                        3334     3349  E   COMPTUEX                     01-84
DDG   44  PRATT WV        N52684
                                        3119     3131  E   EXER      ATLANTIC OCEAN
                                           * * R E M A R K - SOLID SHIELD 83
                                        3148     3157  E   EXER      ATLANTIC OCEAN
                                           * * R E M A R K - UNITED EFFORT
                                        3158     3168  E   EXER      NORTH ATLANTIC
                                           * * R E M A R K - OCEAN SAFARI 83
                                        3180     3188  E   EXER      NORTH ATLANTIC
                                           * * R E M A R K - BALTOPS 83
                                        3189     3198  E   ENR       CONUS
                                        3221     3239  E   COMPTUEX                     04-83
DDG   45  DEWEY           N52685
                                        3107     3136  E   POM
                                        3137     3146  E   ENR       ROTA
                                        3137     3273  C   DEPLOY
                                           * * R E M A R K - MEF 3-83
                                        3147     3163  E   OPCON                        COMIDEASTFOR
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UNIT IDENTIFI:ATION                          START      ENO   EMPLOYMENT     LOCATION         EMP UNIT/EXERCISE NO.

                                                3264    3273  E   ENR       CONUS
                                                3274    3303  E   LVUPK
                                                3334    3349  E   COMPTUEX                      01-84
ODG   46  PREBLE              N52686
                                                3148    3157  E   EXER      ATLANTIC OCEAN
                                                   * * R E M A R K - UNITEO EFFORT
                                                3158    3168  E   EXER      NORTH ATLANTIC
                                                   * * R E M A R K - OCEAN SAFARI 83
                                                3180    3188  E   EXER      NORTH ATLANTIC
                                                   * * R E M A R K - BALTOPS 83
                                                3189    3198  E   ENR       CONUS
OOG  993  KIOD                N21436
                                                3069    3092  E   RFADEX    CARI88EAN SEA       01-83
                                                3093    3122  E   POM
                                                3123    3133  E   ENR       ROTA
                                                3123    3325  C   OEPLOY
                                                   * * R E M A R K - MEO 2-83
                                                3133    3315  E   OPCON                         CINCUSNAVEUR
                                                3316    3325  E   ENR       CONUS
                                                3326    3355  E   LVUPK
DOG  995  SCOTT               N21438
                                                3095    3112  E   COMPTUEX                      02-83
                                                3119    3131  E   EXER      ATLANTIC OCEAN
                                                   * * R E M A R K - SCLID SHIELD 83
                                                3241    3270  E   POM
                                                3271    3281  E   ENR       ROTA
                                                3271    3365  C   OEPLOY
                                                   * * R E M A R K - IO 1-84
                                                3282    3365  E   OPCON                         CINCPACFLT
OO   944  MULLINNIX           M52203
                                                3001    3130  E   OPCON                         CINCUSNAVEUR
                                                3001    3140  C   OEPLOY
                                                   * * R E M A R K - MED 1-83
                                                3131    3140  E   ENR       CONUS
                                                3141    3170  E   LVUPK
DD   963  SPRUANCE            N20574
                                                3001    3030  E   POM
                                                3031    3040  E   ENR       ROTA
                                                3031    3254  C   OEPLOY
                                                   * * R E M A R K - MEF 2-83
                                                3041    3245  E   OPCON                         COMIOEASTFOR
                                                3246    3254  E   ENR       CONUS
                                                3255    3284  E   LVUPK
DC   968  RADFCRD AW          N20588
                                                3069    3092  E   READEX    CARI88EAN SEA       01-83
                                                3093    3122  E   POM
                                                3123    3133  E   ENR       RDTA
                                                3123    3325  C   DEPLOY
                                                   * * R E M A R K - MEO 2-83
                                                3133    3315  E   OPCON                         CINCUSNAVEUR
                                                3316    3325  E   ENR       CONUS
                                                3326    3355  E   LVUPK
OC   969  PETERSDN            N20589
                                                3148    3157  E   EXER      ATLANTIC OCEAN
                                                   * * R E M A R K - UNITEO EFFORT
                                                3158    3168  E   EXEP      NORTH ATLANTIC
                                                   * * R E M A R K - OCEAN SAFARI 83
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UNIT IDENTIFICATION                          START     END  EMPLOYMENT   LOCATION          EMP UNIT/EXERCISE NO.

                                              3180     3188  E   EXER       NORTH ATLANTIC
                                                 * * R E M A R K - BALTOPS 83
                                              3189     3198  E   ENR        CONUS
DD   970  CARON                 N20590
                                              3095     3112  E   COMPTUEX                       02-83
                                              3119     3131  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - SOLID SHIELD 83
                                              3241     3270  E   POM
                                              3271     3281  E   ENR        ROTA
                                              3271     3365  C   DEPLOY
                                                 * * R E M A R K - IO 1-84
DD   974  COMTE DE GRASSE       N20600        3282     3365  E   OPCON                          CINCPACFLT

                                              3001     3010  E   ENR
                                              3001     3211  C   DEPLOY
                                                 * * R E M A R K - SNFL 1-83
                                              3010     3201  E   OPCON                          STANAVFORLANT
                                              3202     3211  E   ENR        CONUS
                                              3212     3242  E   LVUPK
DD   977  BRISCOE               N20603
                                              3334     3349  E   COMPTUEX                       01-84
DD   978  STUMP                 N20604
                                              3001     3064  E   OPCON                          COMIDEASTFOR
                                              3001     3075  C   DEPLOY
                                                 * * R E M A R K - MEF 1-83
                                              3065     3075  E   ENR        CONUS
                                              3076     3105  E   LVUPK
                                              3119     3131  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - SOLID SHIELD 83
DD   979  CONOLLY               N20611        3152     3168  E   COMPTUEX                       03-83

                                              3069     3092  E   READEX     CARIBBEAN SEA       01-83
                                              3093     3122  E   POM
                                              3123     3133  E   ENR        ROTA
                                              3123     3325  C   DEPLOY
                                                 * * R E M A R K - MED 2-83
                                              3133     3315  E   OPCON                          CINCUSNAVEUR
                                              3316     3325  E   ENR        CONUS
                                              3326     3355  E   LVUPK
DD   980  MOOSBRUGGER           N20612
                                              3152     3168  E   COMPTUEX                       03-83
                                              3221     3238  E   COMPTUEX                       04-83
DD   981  HANCOCK J             N20613
DD   982  NICHOLSON             N20614
                                              3095     3112  E   COMPTUEX                       02-83
                                              3221     3238  E   COMPTUEX                       04-83
DD   983  RODGERS J             N20615
                                              3152     3168  E   COMPTUEX                       03-83
                                              3334     3349  E   COMPTUEX                       01-84
DD   987  OBANNON               N20834
                                              3148     3157  E   EXER       ATLANTIC OCEAN
                                                 * * R E M A R K - UNITED EFFORT
                                              3158     3168  E   EXER       NORTH ATLANTIC
                                                 * * R E M A R K - OCEAN SAFARI 83
                                              3180     3188  E   EXER       NORTH ATLANTIC
                                                 * * R E M A R K - BALTOPS 83
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UNIT IDENTIFICATION                          START      END   EMPLOYMENT     LOCATION          EMP UNIT/EXERCISE NO.

                                               3189     3198  E    ENR        CONUS
OD    988  THORN              N20835
                                               3221     3238  E    COMPTUEX                          04-83
                                               3334     3349  E    COMPTUEX                          01-84
DD    997  HAYLCR             N00000
DC    989  DEYJ               N20836
                                               3095     3112  E    COMPTUEX                          02-83
                                               3119     3131  E    EXER       ATLANTIC OCEAN
                                                   * * R E M A R K - SCLID SHIELD 83
                                               3166     3195  E    POM
                                               3196     3205  E    ENR        ROTA
                                               3196     3355  C    DEPLCY
                                                   * * R E M A R K - MEF 4-83
                                               3206     3345  E    OPCON                             COMIDEASTFOR
                                               3346     3355  E    ENR        CONUS
                                               3356     3365  E    LVUPK
FFG     4  TALBCT             N04695
                                               3221     3238  E    COMPTUEX                          04-83
FFG     5  PAGE RL            N04698
FFG     6  FURER JA           N04699
                                               3095     3112  E    COMPTUEX                          02-83
                                               3148     3157  E    EXER       ATLANTIC OCEAN
                                                   * * R E M A R K - UNITED EFFORT
                                               3158     3168  E    EXER       NORTH ATLANTIC
                                                   * * R E M A R K - OCEAN SAFAPI 83
                                               3180     3188  E    EXER       NOPTH ATLANTIC
                                                   * * R E M A R K - BALTOPS 83
                                               3189     3198  E    ENR        CONUS
FFG     7  PERRY OH           N21028
                                               3001     3030  E    POM
                                               3031     3040  E    ENR        ROTA
                                               3031     3254  C    DEPLCY
                                                   * * R E M A R K - MEF 2-83
                                               3041     3245  E    OPCON                             COMIDEASTFOR
                                               3246     3254  E    ENR        CONUS
                                               3255     3284  E    LVUPK
FFG     8  MCINEPNEY          N21032
                                               3001     3130  E    OPCON                             CINCUSNAVEUR
                                               3001     3140  C    DEPLOY
                                                   * * R E M A R K - MED 1-83
                                               3131     3140  E    ENR        CONUS
                                               3141     3170  E    LVUPK
                                               3221     3238  E    COMPTUEX                          04-83
                                               3334     3349  E    COMPTUEX                          01-84
FFG    11  CLARK              N20964
                                               3148     3157  E    EXER       ATLANTIC OCEAN
                                                   * * R E M A R K - UNITED EFFORT
                                               3158     3168  E    EXER       NORTH ATLANTIC
                                                   * * R E M A R K - OCEAN SAFARI 83
                                               3180     3188  E    EXER       NORTH ATLANTIC
                                                   * * R E M A R K - BALTOPS 83
                                               3189     3198  E    ENR        CONUS
                                               3241     3270  E    POM
                                               3271     3281  E    ENR        ROTA
                                               3271     3365  C    DEPLOY
                                                   * * R E M A R K - IO 1-84
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UNIT IDENTIFICATION                   START    END   EMPLOYMENT    LOCATION        EMP UNIT/EXERCISE NO.

                                        3282    3365  E   OPCON                       CINCPACFLT
FFG   13  MORISON SE        N20966
                                        3152    3168  E   COMPTUEX                    03-83
                                        3244    3263  E   READEX                      02-83
                                        3264    3293  E   POM
                                        3294    3303  E   ENR         ROTA
                                        3294    3365  C   DEPLOY
                                           * * R E M A R K - MED 1-84
                                        3304    3365  E   OPCON                       CINCUSNAVEUR
FFG   15  ESTOCIN           N20968
                                        3095    3112  E   COMPTUEX                    02-83
                                        3152    3168  E   COMPTUEX                    03-83
                                        3221    3238  E   COMPTUEX                    04-83
                                        3334    3349  E   COMPTUEX                    01-84
FFG   16  SPRAGUE C         N20969
                                        3001    3130  E   OPCON                       CINCUSNAVEUR
                                        3001    3140  C   DEPLOY
                                           * * R E M A R K - MED 1-83
                                        3131    3140  E   ENR         CONUS
                                        3141    3170  E   LVUPK
                                        3221    3238  E   COMPTUEX                    04-83
                                        3334    3349  E   COMPTUEX                    01-84
FFG   20  ANTRIM            N20973
                                        3095    3112  E   COMPTUEX                    02-83
                                        3244    3263  E   READEX                      02-83
                                        3264    3293  E   POM
                                        3294    3303  E   ENR         ROTA
                                        3294    3365  C   DEPLOY
                                           * * R E M A R K - MED 1-84
                                        3304    3365  E   OPCON                       CINCUSNAVEUR
FFG   21  FLATLEY           N20974
                                        3095    3112  E   COMPTUEX                    02-83
                                        3244    3263  E   READEX                      02-83
                                        3264    3293  E   POM
                                        3294    3303  E   ENR         ROTA
                                        3294    3365  C   DEPLOY
                                           * * R E M A R K - MED 1-84
                                        3304    3365  E   OPCON                       CINCUSNAVEUR
FFG   22  FARION            N20975
                                        3148    3157  E   EXER        ATLANTIC OCEAN
                                           * * R E M A R K - UNITED EFFORT
                                        3158    3168  E   EXER        NORTH ATLANTIC
                                           * * R E M A R K - OCEAN SAFARI 83
                                        3180    3188  E   EXER        NORTH ATLANTIC
                                           * * R E M A R K - BALTOPS 83
                                        3189    3198  E   ENR         CONUS
FFG   24  WILLIAMS J        N20977
                                        3152    3168  E   COMPTUEX                    03-83
                                        3244    3263  E   READEX                      02-83
                                        3264    3293  E   POM
                                        3294    3303  E   ENR         ROTA
                                        3294    3365  C   DEPLOY
                                           * * R E M A R K - MED 1-84
                                        3304    3365  E   OPCON                       CINCUSNAVEUR
FFG   26  GALLERY           N20979
                                        3095    3112  E   COMPTUEX                    02-83
```

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UNIT IDENTIFICATION                          START      END   EMPLOYMENT     LOCATION          EMP UNIT/EXERCISE NO.

                                                3244    3263  E   READEX                         02-83
                                                3264    3293  E   POM
                                                3294    3303  E   ENR       ROTA
                                                3294    3365  C   DEPLOY
                                                    * * R E M A R K - MED 1-84
                                                3304    3365  E   OPCON                          CINCUSNAVEUR
FFG   28  BOONE               N21053
                                                3221    3238  E   COMPTUEX                       04-83
FFG   29  GROVES SW           N21054
                                                3334    3349  E   COMPTUEX                       01-84
FFG   31  STARK               N21056
FFG   32  HALL JL             N21057
                                                3334    3349  E   COMPTUEX                       01-84
FFG   34  FITCH A             N21059
FF  1038  MCCLOY              N54036
                                                3119    3131  E   EXER      ATLANTIC OCEAN
                                                    * * R E M A R K - SOLID SHIELD 83
                                                3152    3168  E   COMPTUEX                       03-83
                                                3244    3263  E   READEX                         02-83
                                                3264    3293  E   POM
                                                3294    3303  E   ENR       ROTA
                                                3294    3365  C   DEPLOY
                                                    * * R E M A R K - MED 1-84
                                                3304    3365  E   OPCON                          CINCUSNAVEUR
FF  1040  GARCIA              N54037
                                                3095    3112  E   COMPTUEX                       02-83
                                                3166    3195  E   POM
                                                3196    3205  E   ENR       ROTA
                                                3196    3355  C   DEPLOY
                                                    * * R E M A R K - MEF 4-83
                                                3206    3345  E   OPCON                          COMIDEASTFOR
                                                3346    3355  E   ENR       CONUS
                                                3356    3365  E   LVUPK
FF  1043  MCDONNELL E         N54039
                                                3001    3130  E   OPCON                          CINCUSNAVEUR
                                                3001    3140  C   DEPLOY
                                                    * * R E M A R K - MED 1-83
                                                3131    3140  E   ENR       CONUS
                                                3141    3170  E   LVUPK
                                                3221    3238  E   COMPTUEX                       04-83
                                                3334    3349  E   COMPTUEX                       01-84
FF  1044  BRUMBY              N54040
                                                3001    3143  E   OPCON                          CINCPACFLT
                                                3001    3153  C   DEPLOY
                                                    * * R E M A R K - IO 1-83
                                                3144    3153  E   ENR       CONUS
                                                3154    3183  E   LVUPK
FF  1047  VOGE                N54042
FF  1049  KOELSCH             N54044
FF  1056  CONNOLE             N54051
                                                3001    3130  E   OPCON                          CINCUSNAVEUR
                                                3001    3140  C   DEPLOY
                                                    * * R E M A R K - MED 1-83
                                                3131    3140  E   ENR       CONUS
                                                3141    3170  E   LVUPK
                                                3221    3238  E   COMPTUEX                       04-83
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UNIT IDENTIFICATION                          START    END   EMPLOYMENT     LOCATION          EMP UNIT/EXERCISE NO.

                                              3334    3349  E   COMPTUEX                        01-84
FF  1059  SIMS WS           N54054
                                              3119    3131  E   EXER       ATLANTIC OCEAN
                                                * * R E M A R K - SOLID SHIELD 83
                                              3152    3168  E   COMPTUEX                        03-83
                                              3221    3238  E   COMPTUEX                        04-83
                                              3244    3263  E   READEX                          02-83
                                              3264    3293  E   POM
                                              3294    3303  E   ENR        ROTA
                                              3294    3365  C   DEPLCY
                                                * * R E M A R K - MED 1-84
                                              3304    3365  E   OPCON                           CINCUSNAVEUR
FF  1061  PATTERSON         N54056
                                              3152    3168  E   COMPTUEX                        03-83
                                              3334    3349  E   COMPTUEX                        01-84
FF  1068  VREELAND          N54063
                                              3069    3092  E   READEX     CARIBBEAN SEA        01-83
                                              3093    3122  E   POM
                                              3123    3133  E   ENR        ROTA
                                              3123    3325  C   DEPLOY
                                                * * R E M A R K - MED 2-83
                                              3133    3315  E   OPCON                           CINCUSNAVEUR
                                              3316    3325  E   ENR        CONUS
                                              3326    3355  E   LVUPK
FF  1072  BLAKELY           N54067
                                              3095    3112  E   COMPTUEX                        02-83
                                              3119    3131  E   EXER       ATLANTIC OCEAN
                                                * * R E M A R K - SOLID SHIELD 83
FF  1075  TRIPPE            N54070
                                              3069    3092  E   READEX     CARIBBEAN SEA        01-83
                                              3093    3122  E   POM
                                              3123    3133  E   ENR        ROTA
                                              3123    3325  C   DEPLOY
                                                * * R E M A R K - MED 2-83
                                              3133    3315  E   OPCON                           CINCUSNAVEUR
                                              3316    3325  E   ENR        CONUS
                                              3326    3355  E   LVUPK
FF  1078  HEWES J           N20049
                                              3069    3092  E   READEX     CARIBBEAN SEA        01-83
                                              3093    3122  E   POM
                                              3123    3133  E   ENR        ROTA
                                              3123    3325  C   DEPLCY
                                                * * R E M A R K - MED 2-83
                                              3133    3315  E   OPCON                           CINCUSNAVEUR
                                              3316    3325  E   ENR        CONUS
                                              3326    3355  E   LVUPK
FF  1079  BOWEN             N20050
                                              3107    3136  E   POM
                                              3137    3146  E   ENR        ROTA
                                              3137    3273  C   DEPLCY
                                                * * R E M A R K - MEF 3-83
                                              3147    3163  E   OPCON                           COMIDEASTFOR
                                              3264    3273  E   ENR        CONUS
                                              3274    3303  E   LVUPK
                                              3334    3349  E   COMPTUEX                        01-84
FF  1080  PAUL              N20051
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UNIT IDENTIFICATION                           START      END   EMPLOYMENT     LOCATION         EMP UNIT/EXERCISE NO.

                                                 3095    3112   E   COMPTUEX                      02-83
                                                 3152    3168   E   COMPTUEX                      03-83
                                                 3241    3270   E   POM
                                                 3271    3281   E   ENR       ROTA
                                                 3271    3365   C   DEPLOY
                                                    * * R E M A R K - IO 1-84
                                                 3282    3365   E   OPCON                         CINCPACFLT
FF  1081  AYLWIN              N20052
                                                 3119    3131   E   EXER      ATLANTIC OCEAN
                                                    * * R E M A R K - SOLID SHIELD 83
                                                 3152    3168   E   COMPTUEX                      03-83
                                                 3244    3263   E   READEX                        02-83
                                                 3264    3293   E   POM
                                                 3294    3303   E   ENR       ROTA
                                                 3294    3365   C   DEPLOY
                                                    * * R E M A R K - MED 1-84
                                                 3304    3365   E   OPCON                         CINCUSNAVEUR
FF  1082  MONTGOMERY E        N20053
FF  1084  MCCANDLESS          N20055
FF  1085  BEARY DB            N20056

                                                 3031    3061   E   POM
                                                 3062    3071   E   ENR       ROTA
                                                 3062    3255   C   DEPLOY
                                                    * * R E M A R K - IC 2-83
                                                 3071    3246   E   OPCON                         CINCPACFLT
                                                 3246    3255   E   ENR       CONUS
                                                 3256    3285   E   LVUPK
FF  1089  BROWN JL            N20067
                                                 3095    3112   E   COMPTUEX                      02-83
                                                 3121    3151   E   POM
                                                 3152    3344   E   OPCON                         COMSOLANT
                                                 3152    3344   C   DEPLOY
                                                    * * R E M A R K - UNITAS - WATC
                                                 3345    3365   E   LVUPK
FF  1090  AINSWORTH           N20068
                                                 3001    3130   E   OPCON                         CINCUSNAVEUR
                                                 3001    3140   C   DEPLOY
                                                    * * R E M A R K - MED 1-83
                                                 3131    3140   E   ENR       CONUS
                                                 3141    3170   E   LVUPK
                                                 3221    3238   E   COMPTUEX                      04-83
FF  1091  MILLER              N20069
                                                 3069    3092   E   READEX    CARIBBEAN SEA       01-83
                                                 3093    3122   E   POM
                                                 3123    3133   E   ENR       ROTA
                                                 3123    3325   C   DEPLOY
                                                    * * R E M A R K - MED 2-83
                                                 3133    3315   E   OPCON                         CINCUSNAVEUR
                                                 3316    3325   E   ENR       CONUS
                                                 3326    3355   E   LVUPK
FF  1092  HART TC             N20070
                                                 3095    3112   E   COMPTUEX                      02-83
                                                 3119    3131   E   EXER      ATLANTIC OCEAN
                                                    * * R E M A R K - SOLID SHIELD 83
                                                 3121    3151   E   POM
                                                 3152    3344   E   OPCON                         COMSOLANT
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UNIT IDENTIFICATION                        START      END   EMPLOYMENT     LOCATION         EMP UNIT/EXERCISE NO.

                                            3152      3344  C   DEPLOY
                                               * * R E M A R K - UNITAS - WATC
                                            3345      3365  E   LVUPK
FF  1093  CAPODANNO          N20071
                                            3001      3130  E   OPCON                        CINCUSNAVEUR
                                            3001      3140  C   DEPLOY
                                               * * R E M A R K - MED 1-83
                                            3131      3140  E   ENR          CONUS
                                            3141      3170  E   LVUPK
FF  1094  PHARRIS            N20072
                                            3031      3061  E   POM
                                            3062      3071  E   ENR          ROTA
                                            3062      3255  C   DEPLOY
                                               * * R E M A R K - IC 2-83
                                            3071      3246  E   OPCON                        CINCPACFLT
                                            3246      3255  E   ENR          CONUS
                                            3256      3285  E   LVUPK
FF  1095  TRUETT             N20073
                                            3119      3131  E   EXER         ATLANTIC OCEAN
                                               * * R E M A R K - SOLID SHIELD 83
                                            3148      3157  E   EXER         ATLANTIC OCEAN
                                               * * R E M A R K - UNITED EFFORT
                                            3158      3168  E   EXER         NORTH ATLANTIC
                                               * * R E M A R K - OCEAN SAFARI 83
                                            3180      3188  E   EXER         NORTH ATLANTIC
                                               * * R E M A R K - BALTOPS 83
                                            3189      3198  E   ENR          CONUS
FF  1096  VALDEZ             N20074
                                            3069      3092  E   READEX       CARIBBEAN SEA     01-83
                                            3093      3122  E   POM
                                            3123      3133  E   ENR          ROTA
                                            3123      3325  C   DEPLOY
                                               * * R E M A R K - MED 2-83
                                            3133      3315  E   OPCON                        CINCUSNAVEUR
                                            3316      3325  E   ENR          CONUS
                                            3326      3355  E   LVUPK
FF  1097  MOINESTER          N20075
                                            3069      3092  E   READEX       CARIBBEAN SEA     01-83
                                            3093      3122  E   POM
                                            3123      3133  E   ENR          ROTA
                                            3123      3325  C   DEPLOY
                                               * * R E M A R K - MED 2-83
                                            3133      3315  E   OPCON                        CINCUSNAVEUR
                                            3316      3325  E   ENR          CONUS
                                            3326      3355  E   LVUPK
FF  1098  GLOVER             N17700
                                            3001      3130  E   OPCON                        CINCUSNAVEUR
                                            3001      3140  C   DEPLOY
                                               * * R E M A R K - MED 1-83
                                            3131      3140  E   ENR          CONUS
                                            3141      3170  E   LVUPK
                                            3221      3238  E   COMPTUEX                     04-83
                                            3334      3349  E   COMPTUEX                     01-84
```

APPENDIX F

SAMPLE SOLVER OUTPUT REPORT

The Solver Output Report is a partial output report from the X System. The report lists all CPSKED row constraints with their associated ranges, penalties, and final solution values. The second part of the report lists the final solution by column, column cost, and column elements. Total solution time is printed at the bottom of the report.

```
EVENTLG SOLUTION OUTPUT

     SYMBOL   CON      G-LOWER RNG      G-VAL     G-UPPER RNG   LOWER PEN      PENALTY UPPER PEN

SHIP-SCHEDULE CONSTRAINTS FOLLOW:
         G      1     0.1000D+01   0.1000D+01   0.1000D+01   0.1000D+04   0.0            0.1000D+07
         G      2     0.1000D+01   0.1000D+01   0.1000D+01   0.1000D+04   0.0            0.1000D+07
         G      3     0.1000D+01   0.1000D+01   0.1000D+01   0.1278D+04   0.0            0.1000D+07
         G      4     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G      5     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G      6     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G      7     0.1000D+01   0.1000D+01   0.1000D+01   0.1183D+05   0.0            0.1000D+07
         G      8     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G      9     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     10     0.1000D+01   0.1000D+01   0.1000D+01   0.4191D+04   0.0            0.1000D+07
         G     11     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     12     0.1000D+01   0.1000D+01   0.1000D+01   0.1448D+04   0.0            0.1000D+07
         G     13     0.1000D+01   0.1000D+01   0.1000D+01   0.1367D+04   0.0            0.1000D+07
         G     14     0.1000D+01   0.1000D+01   0.1000D+01   0.1031D+04   0.0            0.1000D+07
         G     15     0.1000D+01   0.1000D+01   0.1000D+01   0.1482D+04   0.0            0.1000D+07
         G     16     0.1000D+01   0.1000D+01   0.1000D+01   0.1117D+04   0.0            0.1000D+07
         G     17     0.1000D+01   0.1000D+01   0.1000D+01   0.1187D+04   0.0            0.1000D+07
         G     18     0.1000D+01   0.1000D+01   0.1000D+01   0.1000D+04   0.0            0.1000D+07
         G     19     0.1000D+01   0.1000D+01   0.1000D+01   0.1007D+05   0.0            0.1000D+07
         G     20     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     21     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     22     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     23     0.1000D+01   0.1000D+01   0.1000D+01   0.1407D+04   0.0            0.1000D+07
         G     24     0.1000D+01   0.1000D+01   0.1000D+01   0.1004D+04   0.0            0.1000D+07
         G     25     0.1000D+01   0.1000D+01   0.1000D+01   0.1281D+04   0.0            0.1000D+07
         G     26     0.1000D+01   0.1000D+01   0.1000D+01   0.1344D+04   0.0            0.1000D+07
         G     27     0.1000D+01   0.1000D+01   0.1000D+01   0.1456D+04   0.0            0.1000D+07
         G     28     0.1000D+01   0.1000D+01   0.1000D+01   0.1595D+05   0.0            0.1000D+07
         G     29     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     30     0.1000D+01   0.1000D+01   0.1000D+01   0.1072D+04   0.0            0.1000D+07
         G     31     0.1000D+01   0.1000D+01   0.1000D+01   0.3351D+04   0.0            0.1000D+07
         G     32     0.1000D+01   0.1000D+01   0.1000D+01   0.1391D+04   0.0            0.1000D+07
         G     33     0.1000D+01   0.1000D+01   0.1000D+01   0.1497D+04   0.0            0.1000D+07
         G     34     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     35     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     36     0.1000D+01   0.1000D+01   0.1000D+01   0.1298D+04   0.0            0.1000D+07
         G     37     0.1000D+01   0.1000D+01   0.1000D+01   0.3759D+04   0.0            0.1000D+07
         G     38     0.1000D+01   0.1000D+01   0.1000D+01   0.1114D+04   0.0            0.1000D+07
         G     39     0.1000D+01   0.1000D+01   0.1000D+01   0.1171D+04   0.0            0.1000D+07
         G     40     0.1000D+01   0.1000D+01   0.1000D+01   0.1322D+05   0.0            0.1000D+07
         G     41     0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0            0.1000D+07
         G     42     0.1000D+01   0.1000D+01   0.1000D+01   0.3374D+04   0.0            0.1000D+07
         G     43     0.1000D+01   0.1000D+01   0.1000D+01   0.2171D+04   0.0            0.1000D+07
         G     44     0.1000D+01   0.1000D+01   0.1000D+01   0.1323D+04   0.0            0.1000D+07
```

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G     45    0.1000D+01   0.1000D+01   0.1000D+01   0.1522D+04   0.0          0.1000D+07
G     46    0.1000D+01   0.1000D+01   0.1000D+01   0.1411D+04   0.0          0.1000D+07
G     47    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     48    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     49    0.1000D+01   0.1000D+01   0.1000D+01   0.1371D+04   0.0          0.1000D+07
G     50    0.1000D+01   0.1000D+01   0.1000D+01   0.1249D+04   0.0          0.1000D+07
G     51    0.1000D+01   0.1000D+01   0.1000D+01   0.1387D+04   0.0          0.1000D+07
G     52    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     53    0.1000D+01   0.1000D+01   0.1000D+01   0.1112D+04   0.0          0.1000D+07
G     54    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     55    0.1000D+01   0.1000D+01   0.1000D+01   0.9597D+04   0.0          0.1000D+07
G     56    0.1000D+01   0.1000D+01   0.1000D+01   0.1218D+04   0.0          0.1000D+07
G     57    0.1000D+01   0.1000D+01   0.1000D+01   0.1028D+04   0.0          0.1000D+07
G     58    0.1000D+01   0.1000D+01   0.1000D+01   0.1278D+04   0.0          0.1000D+07
G     59    0.1000D+01   0.1000D+01   0.1000D+01   0.1195D+04   0.0          0.1000D+07
G     60    0.1000D+01   0.1000D+01   0.1000D+01   0.1305D+04   0.0          0.1000D+07
G     61    0.1000D+01   0.1000D+01   0.1000D+01   0.1204D+04   0.0          0.1000D+07
G     62    0.1000D+01   0.1000D+01   0.1000D+01   0.1027D+04   0.0          0.1000D+07
G     63    0.1000D+01   0.1000D+01   0.1000D+01   0.4367D+04   0.0          0.1000D+07
G     64    0.1000D+01   0.1000D+01   0.1000D+01   0.1148D+04   0.0          0.1000D+07
G     65    0.1000D+01   0.1000D+01   0.1000D+01   0.1000D+04   0.0          0.1000D+07
G     66    0.1000D+01   0.1000D+01   0.1000D+01   0.1103D+04   0.0          0.1000D+07
G     67    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     68    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     69    0.1000D+01   0.1000D+01   0.1000D+01   0.1133D+04   0.0          0.1000D+07
G     70    0.1000D+01   0.1000D+01   0.1000D+01   0.1109D+04   0.0          0.1000D+07
G     71    0.1000D+01   0.1000D+01   0.1000D+01   0.1147D+04   0.0          0.1000D+07
G     72    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     73    0.1000D+01   0.1000D+01   0.1000D+01   0.1439D+04   0.0          0.1000D+07
G     74    0.1000D+01   0.1000D+01   0.1000D+01   0.1439D+04   0.0          0.1000D+07
G     75    0.1000D+01   0.1000D+01   0.1000D+01   0.1316D+04   0.0          0.1000D+07
G     76    0.1000D+01   0.1000D+01   0.1000D+01   0.1439D+04   0.0          0.1000D+07
G     77    0.1000D+01   0.1000D+01   0.1000D+01   0.1448D+04   0.0          0.1000D+07
G     78    0.1000D+01   0.1000D+01   0.1000D+01   0.1106D+04   0.0          0.1000D+07
G     79    0.1000D+01   0.1000D+01   0.1000D+01   0.1056D+04   0.0          0.1000D+07
G     80    0.1000D+01   0.1000D+01   0.1000D+01   0.1000D+04   0.0          0.1000D+07
G     81    0.1000D+01   0.1000D+01   0.1000D+01   0.1070D+04   0.0          0.1000D+07
G     82    0.1000D+01   0.1000D+01   0.1000D+01   0.1006D+04   0.0          0.1000D+07
G     83    0.1000D+01   0.1000D+01   0.1000D+01   0.4414D+04   0.0          0.1000D+07
G     84    0.1000D+01   0.1000D+01   0.1000D+01   0.1452D+04   0.0          0.1000D+07
G     85    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     86    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     87    0.1000D+01   0.1000D+01   0.1000D+01   0.1046D+04   0.0          0.1000D+07
G     88    0.1000D+01   0.1000D+01   0.1000D+01   0.1040D+04   0.0          0.1000D+07
G     89    0.1000D+01   0.1000D+01   0.1000D+01   0.2500D+06   0.0          0.1000D+07
G     90    0.1000D+01   0.1000D+01   0.1000D+01   0.7199D+04   0.0          0.1000D+07
G     91    0.1000D+01   0.1000D+01   0.1000D+01   0.1195D+04   0.0          0.1000D+07
G     92    0.1000D+01   0.1000D+01   0.1000D+01   0.1808D+04   0.0          0.1000D+07
G     93    0.1000D+01   0.1000D+01   0.1000D+01   0.4208D+04   0.0          0.1000D+07
G     94    0.1000D+01   0.1000D+01   0.1000D+01   0.2597D+04   0.0          0.1000D+07
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     G    95    0.1000D+01  0.1000D+01  0.1000D+01  0.2062D+04  0.0          0.1000D+07
     G    96    0.1000D+01  0.1000D+01  0.1000D+01  0.1211D+04  0.0          0.1000D+07
     G    97    0.1000D+01  0.1000D+01  0.1000D+01  0.1435D+04  0.0          0.1000D+07
     G    98    0.1000D+01  0.1000D+01  0.1000D+01  0.1196D+04  0.0          0.1000D+07
     G    99    0.1000D+01  0.1000D+01  0.1000D+01  0.1049D+04  0.0          0.1000D+07
     G   100    0.1000D+01  0.1000D+01  0.1000D+01  0.1000D+04  0.0          0.1000D+07
     G   101    C.1000D+01  0.1000D+01  0.1000D+01  0.2185D+05  0.0          0.1000D+07
     G   102    0.1000D+01  0.1000D+01  0.1000D+01  0.1856D+05  0.0          0.1000D+07
     G   103    0.1000D+01  0.1000D+01  0.1000D+01  0.2500D+06  0.0          0.1000D+07
     G   104    0.1000D+01  0.1000D+01  0.1000D+01  0.1171D+05  0.0          0.1000D+07
     G   105    0.1000D+01  0.1000D+01  0.1000D+01  0.1405D+05  0.0          0.1000D+07
     G   106    0.1000D+01  0.1000D+01  0.1000D+01  0.2500D+06  0.0          0.1000D+07
     G   107    0.1000D+01  0.1000D+01  0.1000D+01  0.1737D+05  0.0          0.1000D+07
     G   108    0.1000D+01  0.1000D+01  0.1000D+01  0.3669D+04  0.0          0.1000D+07
     G   109    0.1000D+01  0.1000D+01  0.1000D+01  0.7330D+04  0.0          0.1000D+07
     G   110    0.1000D+01  0.1000D+01  0.1000D+01  0.3439D+04  0.0          0.1000D+07
     G   111    0.1000D+01  0.1000D+01  0.1000D+01  0.2500D+06  0.0          0.1000D+07
EVENT/SHIP-TYPE CONSTRAINTS FOLLOW:
     G   112    0.1000D+01  0.1000D+01  0.2000D+01  0.1932D+05  0.0          0.9661D+04
     G   113    0.2000D+01  0.2000D+01  0.3000D+01  0.1932D+05  0.0          0.9661D+04
     G   114    0.2000D+01  0.2000D+01  0.3000D+01  0.1932D+05  C.0          0.9661D+04
     G   115    0.1000D+01  0.1000D+01  0.2000D+01  0.1932D+05  0.0          0.9661D+04
     G   116    0.2000D+01  0.2000D+01  0.3000D+01  0.1932D+05  0.0          0.9661D+04
     G   117    0.5000D+01  0.5000D+01  0.7000D+01  0.1932D+05  0.0          0.9661D+04
     G   118    0.1000D+01  0.1000D+01  0.2000D+01  0.2310D+05  0.0          0.1155D+05
     G   119    0.1000D+01  0.1000D+01  0.2000D+01  0.2310D+05  0.0          0.1155D+05
     G   120    0.1000D+01  0.1000D+01  0.2000D+01  0.2310D+05  0.0          0.1155D+05
     G   121    0.1000D+01  0.1000D+01  0.2000D+01  0.2310D+05  0.0          0.1155D+05
     G   122    0.1000D+01  0.1000D+01  0.2000D+01  0.5476D+04  0.0          0.2738D+04
     G   123    C.1000D+01  0.1000D+01  0.2000D+01  0.5476D+04  0.0          0.2738D+04
     G   124    C.1000D+01  0.1000D+01  0.2000D+01  0.5382D+05  0.0          0.2691D+05
     G   125    0.1000D+01  0.1000D+01  0.2000D+01  0.5382D+05  0.0          0.2691D+05
     G   126    C.1000D+01  0.1000D+01  0.2000D+01  0.4410D+05  0.0          0.2205D+05
     G   127    C.1000D+01  0.1000D+01  0.2000D+01  0.3725D+05  0.0          0.1862D+05
     G   128    0.1000D+01  0.1000D+01  0.2000D+01  0.3725D+05  0.0          0.1862D+05
     G   129    0.1000D+01  0.2000D+01  0.2000D+01  0.3725D+05  0.0          0.1862D+05
     G   130    C.1000D+01  0.2000D+01  0.2000D+01  0.3725D+05  0.0          0.1862D+05
     G   131    0.1000D+01  0.1000D+01  0.2000D+01  0.5063D+05  0.0          0.2531D+05
     G   132    0.2000D+01  0.2000D+01  0.3000D+01  0.5063D+05  0.0          0.2531D+05
     G   133    0.2000D+01  0.2000D+01  0.3000D+01  0.5063D+05  0.0          0.2531D+05
     G   134    0.2000D+01  0.2000D+01  0.3000D+01  0.5063D+05  0.0          0.2531D+05
     G   135    0.3000D+01  0.3000D+01  0.5000D+01  0.5063D+05  0.0          0.2531D+05
     G   136    0.3000D+01  0.3000D+01  0.5000D+01  0.5063D+05  0.0          0.2531D+05
     G   137    C.2000D+01  0.3000D+01  0.3000D+01  0.2890D+03  0.0          0.1445D+03
     G   138    0.2000D+01  0.3000D+01  0.3000D+01  0.2890D+03  0.0          0.1445D+03
     G   139    C.2000D+01  0.3000D+01  0.3000D+01  0.2890D+03  0.0          0.1445D+03
     G   140    0.3000D+01  0.5000D+01  0.5000D+01  0.2890D+03  0.0          0.1445D+03
     G   141    0.3000D+01  0.5000D+01  0.5000D+01  0.2890D+03  0.0          0.1445D+03
     G   142    C.1000D+01  0.1000D+01  0.2000D+01  0.1850D+05  0.0          0.9248D+04
     G   143    C.1000D+01  0.1000D+01  0.2000D+01  0.1850D+05  0.0          0.9248D+04
     G   144    0.1000D+01  0.2000D+01  0.2000D+01  0.1440D+03  0.0          0.7200D+02
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          G     145     0.2000D+01   0.3000D+01   0.3000D+01   0.1440D+03   0.0          0.7200D+02
          G     146     0.2000D+01   0.3000D+01   0.3000D+01   0.1440D+03   0.0          0.7200D+02
          G     147     0.2000D+01   0.3000D+01   0.3000D+01   0.1440D+03   0.0          0.7200D+02
          G     148     0.2000D+01   0.3000D+01   0.3000D+01   0.1440D+03   0.0          0.7200D+02
          G     149     0.2000D+01   0.3000D+01   0.3000D+01   0.1440D+03   0.0          0.7200D+02
          G     150     0.1000D+01   0.1000D+01   0.2000D+01   0.3764D+05   0.0          0.1882D+05
          G     151     0.1000D+01   0.1000D+01   0.2000D+01   0.1296D+04   0.0          0.6480D+03
          G     152     0.2000D+01   0.3000D+01   0.3000D+01   0.1296D+04   0.0          0.6480D+03
          G     153     0.1000D+01   0.2000D+01   0.2000D+01   0.1296D+04   0.0          0.6480D+03
          G     154     0.2000D+01   0.3000D+01   0.3000D+01   0.1296D+04   0.0          0.6480D+03
          G     155     0.2000D+01   0.3000D+01   0.3000D+01   0.1296D+04   0.0          0.6480D+03
          G     156     0.2000D+01   0.3000D+01   0.3000D+01   0.2560D+03   0.0          0.1280D+03
          G     157     0.2000D+01   0.3000D+01   0.3000D+01   0.2560D+03   0.0          0.1280D+03
          G     158     0.2000D+01   0.3000D+01   0.3000D+01   0.2560D+03   0.0          0.1280D+03
          G     159     0.3000D+01   0.3000D+01   0.5000D+01   0.2560D+03   0.0          0.1280D+03
          G     160     0.3000D+01   0.5000D+01   0.5000D+01   0.2560D+03   0.0          0.1280D+03
          G     161     0.1000D+01   0.1000D+01   0.2000D+01   0.3686D+05   0.0          0.1843D+05
          G     162     0.1000D+01   0.1000D+01   0.2000D+01   0.3686D+05   0.0          0.1843D+05
          G     163     0.1000D+01   0.1000D+01   0.2000D+01   0.3686D+05   0.0          0.1843D+05
          G     164     0.1000D+01   0.1000D+01   0.2000D+01   0.2528D+05   0.0          0.1264D+05
          G     165     0.1000D+01   0.1000D+01   0.2000D+01   0.2528D+05   0.0          0.1264D+05
          G     166     0.2000D+01   0.3000D+01   0.3000D+01   0.2890D+03   0.0          0.1445D+03
          G     167     0.2000D+01   0.3000D+01   0.3000D+01   0.2890D+03   0.0          0.1445D+03
          G     168     0.2000D+01   0.3000D+01   0.3000D+01   0.2890D+03   0.0          0.1445D+03
          G     169     0.3000D+01   0.5000D+01   0.5000D+01   0.2890D+03   0.0          0.1445D+03
          G     170     0.3000D+01   0.5000D+01   0.5000D+01   0.2890D+03   0.0          0.1445D+03
          G     171     0.1000D+01   0.1000D+01   0.2000D+01   0.8836D+04   0.0          0.4418D+04
          G     172     0.1000D+01   0.2000D+01   0.2000D+01   0.8836D+04   0.0          0.4418D+04
          G     173     0.1000D+01   0.2000D+01   0.2000D+01   0.8836D+04   0.0          0.4418D+04
          G     174     0.1000D+01   0.1000D+01   0.2000D+01   0.8100D+04   0.0          0.4050D+04
          G     175     0.2000D+01   0.3000D+01   0.3000D+01   0.8100D+04   0.0          0.4050D+04
          G     176     0.2000D+01   0.2000D+01   0.3000D+01   0.8100D+04   0.0          0.4050D+04
          G     177     0.2000D+01   0.2000D+01   0.3000D+01   0.8100D+04   0.0          0.4050D+04
          G     178     0.3000D+01   0.3000D+01   0.5000D+01   0.8100D+04   0.0          0.4050D+04
          G     179     0.3000D+01   0.3000D+01   0.5000D+01   0.8100D+04   0.0          0.4050D+04
          G     180     0.2000D+01   0.3000D+01   0.3000D+01   0.2250D+03   0.0          0.1125D+03
          G     181     0.2000D+01   0.3000D+01   0.3000D+01   0.2250D+03   0.0          0.1125D+03
          G     182     0.2000D+01   0.3000D+01   0.3000D+01   0.2250D+03   0.0          0.1125D+03
          G     183     0.3000D+01   0.5000D+01   0.5000D+01   0.2250D+03   0.0          0.1125D+03
          G     184     0.3000D+01   0.5000D+01   0.5000D+01   0.2250D+03   0.0          0.1125D+03
WEAPON  SYSTEM CAPABILITY CONSTRAINTS FOLLOW:
          G     185     0.2000D+01   0.1000D+01   0.7000D+01   0.1000D+04   0.1000D+04   0.1000D+02
          G     186     0.4000D+01   0.5000D+01   0.9000D+01   0.1000D+04   0.0          0.1000D+02
          G     187     0.3000D+01   0.2000D+01   0.8000D+01   0.1000D+04   0.1000D+04   0.1000D+02
          G     188     0.4000D+01   0.3000D+01   0.9000D+01   0.1000D+04   0.1000D+04   0.1000D+02
          G     189     0.3000D+01   0.5000D+01   0.8000D+01   0.1000D+04   0.0          0.1000D+02
          G     190     0.3000D+01   0.9000D+01   0.8000D+01   0.1000D+04   0.1000D+02   0.1000D+02
          G     191     0.4000D+01   0.1000D+02   0.9000D+01   0.1000D+04   0.1000D+02   0.1000D+02
          G     192     0.1000D+01   0.2000D+01   0.6000D+01   0.1000D+04   0.0          0.1000D+02
          G     193     0.2000D+01   0.0          0.7000D+01   0.1000D+04   0.2000D+04   0.1000D+02
          G     194     0.2000D+01   0.2000D+01   0.7000D+01   0.1000D+04   0.0          0.1000D+02
          G     195     0.2000D+01   0.1000D+01   0.7000D+01   0.1000D+04   0.1000D+04   0.1000D+02
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G   196   0.2000D+01  0.1000D+01  0.7000D+01  0.1000D+04  0.1000D+04  0.1000D+02
G   197   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   198   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   199   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   200   0.1000D+01  0.2000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   201   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   202   0.2000D+01  0.2000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   203   0.2000D+01  0.2000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   204   0.2000D+01  0.2000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   205   0.2000D+01  0.3000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   206   0.2000D+01  0.1000D+01  0.7000D+01  0.1000D+04  0.1000D+04  0.1000D+02
G   207   0.4000D+01  0.3000D+01  0.9000D+01  0.1000D+04  0.1000D+04  0.1000D+02
G   208   0.3000D+01  0.2000D+01  0.8000D+01  0.1000D+04  0.1000D+04  0.1000D+02
G   209   0.4000D+01  0.5000D+01  0.9000D+01  0.1000D+04  0.0         0.1000D+02
G   210   0.3000D+01  0.8000D+01  0.8000D+01  0.1000D+04  0.0         0.1000D+02
G   211   0.3000D+01  0.1000D+02  0.8000D+01  0.1000D+04  0.2000D+02  0.1000D+02
G   212   0.4000D+01  0.1200D+02  0.9000D+01  0.1000D+04  0.3000D+02  0.1000D+02
G   213   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   214   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   215   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   216   0.1000D+01  0.2000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   217   0.1000D+01  0.1000D+01  0.6000D+01  0.1000D+04  0.0         0.1000D+02
G   218   0.2000D+01  0.2000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   219   0.2000D+01  0.3000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   220   0.2000D+01  0.2000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   221   0.2000D+01  0.4000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   222   0.2000D+01  0.4000D+01  0.7000D+01  0.1000D+04  0.0         0.1000D+02
G   223   0.4000D+01  0.6000D+01  0.9000D+01  0.1000D+04  0.0         0.1000D+02
G   224   0.3000D+01  0.3000D+01  0.8000D+01  0.1000D+04  0.0         0.1000D+02
G   225   0.4000D+01  0.4000D+01  0.9000D+01  0.1000D+04  0.0         0.1000D+02
G   226   0.3000D+01  0.3000D+01  0.8000D+01  0.1000D+04  0.0         0.1000D+02
G   227   0.3000D+01  0.9000D+01  0.8000D+01  0.1000D+04  0.1000D+02  0.1000D+02
G   228   0.4000D+01  0.8000D+01  0.9000D+01  0.1000D+04  0.0         0.1000D+02
```

```
                        OBJECTIVE VALUE =   0.4467D+04
                 SHIP-SCHEDULE PENALTIES =   0.0
               EVENT/SHIP-TYPE PENALTIES =   0.0
WEAPON SYSTEM CAPABILITIES PENALTIES =   0.9080D+04
     1      0.0       1
     2      0.0       2
     4    203.70      3 144
     5  17559.27      4 174
     6  30109.61      5 118
     7  34914.19      6 112 151
     9    156.21      7 144
    10  27344.39      8 131
    11  51027.10      9 127
    25     61.30     10 137 145 156 166 171 217 219
   110   1059.45     11 119 166 180 192 194
   154   2019.28     12 137 175 222 224 225 228
   203   1558.35     13 132 206 208 209 212
   299     31.26     14
   313    173.28     15 137 145 180
   426   7575.79     16 152 175 222 224 225 228
   457     63.49     17 156 180
   465      0.0      18
   467  14987.88     19 132 207 208 209 211 212
   563  18933.37     20 128 202 203 205
   564   2953.18     21 113 186 187 188 190 191
   566   1315.47     22 113 166 186 187 188 190 191
   647   2718.37     23 156 175 222 224 225 227 228
   656      3.60     24
   774    184.20     25 157
   796   6338.39     26 133 207 212
  1035  10214.58     27 138 161
  1164    985.11     28
  1165    154.41     29 114 186 191
  1169     72.01     30
  1173    778.19     31 129 181 202
  1571   3051.61     32 157 176 223 228
  1586  20178.20     33 138 146 150
  1834    184.22     34 122 152
  1846   3766.28     35 114 167 185 188 191
  1909    136.22     36 146 157
  2179   2974.21     37 153 176 222 225 228
  2211    114.12     38
  2215    171.05     39
  2233   1262.79     40 129 201 203
  2336   4236.99     41 120 167 181 192 194
  2499     71.20     42 145 152 167
  2674   2731.97     43 142 181 213
  2905    116.00     44 153
  2943   4883.94     45 133 207 209 211 212
  3188   3770.71     46 138 146 172 218 219 221
  3332    498.73     47 115 191
  3333  31054.19     48 124 199 200
  3337   3021.48     49 134 209 210 211 212
  3553     82.41     50 154
  3598   5519.54     51 139 147 172 219 220 221
```

```
 3734   30024.99       52 126
 3738      57.50       53 182
 3741    1436.96       54 123 147 158 197 198
 3748    3920.61       55 134 209 210 211 212
 4017      66.84       56 158 168
 4035      28.00       57
 4079      97.47       58 139 168
 4189      60.48       59 158 182
 4304     105.49       60 154
 4362      62.04       61 168 182
 4367      26.95       62
 4396   13732.32       63 139 147 164 215 216
 4600      77.09       64 169
 4603       0.0        65
 4693     123.85       66 140 155
 4907   25491.19       67 125 200
 4910       8.70       68 116 169 183 186 190
 5177     242.22       69 155 173 218 221
 5473     160.68       70 159 179 223 227
 5603      24.43       71 140 159 169 183
 5778       3.82       72 116 169 183 186 190
 5878     241.75       73 140 179 223 227
 6119     216.97       74 140 178 223 227
 6426     111.73       75 155
 6694     222.90       76 159 178 223 227
 6806     825.59       77 140 178 223 227
 6954      47.38       78 169
 6958      20.14       79 183
 6959       0.0        80
 6961      29.01       81 183
 6962       6.23       82
 7132      72.88       83 148 160 177 226 227 228
 7249    5683.50       84 141 165 216
 7375      16.76       85 117 170 184 189 190 191
 7377      74.05       86 121 195 196
 7380      46.09       87
 7382      39.56       88
 7386      56.51       89 117 170 184 189 190 191
 7521     722.53       90 149 160 170 177 226 227 228
 7634      60.48       91 160 184
 7646    1506.87       92 135 210 211 212
 7924      53.81       93 141 148
 7931    3335.04       94 136 210 211 212
 8184     277.25       95 135 210 211 212
 8493    2764.55       96 143 184 214
 8681    3159.01       97 141 160 173 220 221
 8916    2549.95       98 149 160 179 226 227 228
 9013      48.84       99
 9015       0.0       100
 9017    1531.31      101 130 204 205
 9233    4154.07      102 141 163
 9377     135.15      103 117 170 189 190 191
 9381    2045.05      104 136 210 211 212
 9674    4680.98      105 141 149 162
 9915    1790.74      106 117 189 190 191
 9917    6565.31      107 130 204 205
10148      19.66      108 148 154
10173    3555.12      109 136 210 211 212
10452    2552.99      110 135 210 211 212
10722     405.18      111 117 170 184 189 190 191
SOLUTION TIME=   82.36
```

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